THE FEEDING OF CROPS AND STOCK

BY THE SAME AUTHOR

THE SOIL
An introduction to the Scientific Study of the growth of Crops.

FERTILISERS AND MANURES

AGRICULTURE AFTER THE WAR

THE FEEDING OF CROPS AND STOCK

AN INTRODUCTION TO THE SCIENCE OF THE NUTRITION OF PLANTS AND ANIMALS

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PART III

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INTRODUCTION

SINCE the original edition of this book the science of nutrition has made great advances. At the time it was written the work of Armsby and of Kellner had been imperfectly assimilated into practice, vitamins and mineral deficiencies were unrecognized.

In consequence I have entirely rewritten the section of the book dealing with the nutrition of animals and I have added a chapter on human nutrition in view of the importance of a more general understanding of this vital subject.

The book is intended in the first instance for students at the Agricultural Colleges and Farm Institutes, but it should also be useful to any farmer who wants to ration his livestock healthily and economically.

I have endeavoured to supply a simple exposition of the scientific principles that underlie the excellent practical instructions on rationing that are contained in the various bulletins published by the Ministry of Agriculture. The feeding of animals is an intricate art, and though the watchful eye of the skilled stockman will ever remain indispensable, his master who has to buy and apportion the feeding stuffs will find it worth while to acquire such an understanding of the materials and processes involved as is set out here.

Sir Frederick Gowland Hopkins and Mr. E. T. Halnan have been good enough to read and advise me

on sections of the book ; I have also to thank Dr. John Hammond, F.R.S., for the sketch of the ruminants' digestive tract and Miss Brenhilda Schafer for much help with the proofs and other material of the book.

A. D. HALL.

MERTON, 1937.

CONTENTS

CHAPTER I

THE ANIMAL

CHAPTER II

ENERGY REQUIRED FOR MAINTENANCE

CHAPTER III

THE PRODUCTIVE RATION

CONTENTS

CHAPTER IV

FEEDING FOR PRODUCTION

CHAPTER V

THE COMPOSITION OF FEEDING STUFFS

CHAPTER VI

FOOD ACCESSORIES

CHAPTER VII

RATIONS FOR LIVE STOCK

CHAPTER VIII

VALUATION

CONTENTS

CHAPTER IX

HUMAN DIETARIES

ILLUSTRATIONS

CHAPTER I

THE ANIMAL

The Animal as a Machine liberating Energy by the combustion of complex Carbon Compounds which previously have been built up by Plants from simple inorganic materials by means of energy derived from Light. Plant Constituents serving as Food—Carbohydrates, Fats and Proteins, with Minerals and Vitamins. The Digestive Tract and its Enzymes which convert the Food Constituents into simpler substances that being soluble can enter the Blood Stream. The Digestive Tract of the Human Being and of the Ruminant Animal. Fuel Value of Food. Deductions for fuel value of undigested Fæces, Urea and Methane. Equivalence of Heat and Work

IN the animal we have to deal with a machine which works in the opposite way to the course of existence pursued by the plant. The plant is a constructive organism ; it takes certain simple substances—carbon dioxide, water, ammonia and a few mineral salts, and out of them it constructs a diversity of compounds of carbon—carbohydrates, fats, proteins and many more complex substances. From the point of view of energy —power to do work—this is an up-grade process. Carbon dioxide and water are substances possessing very little available energy, they are the end products of natural processes like burning, we can compare them to clocks that have run down. But the results of plant growth, collectively or individually, possess energy which can be liberated and made use of in

various ways. We can burn a tree and get thereby heat to warm our rooms and to turn water into steam and drive an engine, which in turn will transform the energy into electricity, whence again can come power or light or heat. The plant effects these combinations and building-up processes by drawing upon the energy contained in the sun's light—that is the original source of power to drive our universe.

We have seen how a plant manufactures sugar and starch from water and the carbon dioxide of the air using the energy from light to effect the change, so that the sugar and starch are stored with energy absorbed by the green leaf. In the animal the sugar and starch are burnt back to carbonic acid and water (the required oxygen being taken from the air breathed in) and the energy originally derived from the sun is made manifest again in the warmth of the body or in muscular work. The plant is thus an up-grade creative organism drawing its energy from the sun ; the animal is a down-grade destructive organism, drawing its energy from its food, materials that have been elaborated by plants. The plant works from simple to more complex compounds of carbon ; the animal, on the contrary, works downwards again ; such special products as animals manufacture are in the main re-arrangements of groups previously built up by the plant. While the animal fully oxidizes the carbon compounds to carbon dioxide, it only breaks down the proteins as far as urea, a comparatively simple amide containing carbon, oxygen, nitrogen and hydrogen. Lastly, a portion of the food resists the digestive processes and, with some other waste products, is excreted in the fæces.

The main substances built up by the plant which

serve as food both of men and animals are the carbohydrates, the fats and oils, the proteins, and the mineral constituents which we find in the plant's ash. Of course there are many other substances in the plant products used for food which also possess a nutritive value. For example, the vegetable acids, such as the citric acid of the orange or the malic acid of the apple, are compounds of carbon, hydrogen and oxygen and get burnt up like the carbohydrates. Again, plants, especially when green and immature, contain amino-acids and other compounds of nitrogen and carbon which are preliminary stages in the building up of proteins: they, like the proteins, are broken down by the animal to urea.

Of the carbohydrates the sugars and the starches are among the chief suppliers of energy to the animal and they may be regarded simply as fuel to maintain the warmth and drive the machine of the body. The sugars are soluble and can pass directly into the blood tract, but the starches require a preliminary conversion into sugars in the digestive tract. In plants there are many other more complex carbohydrates, built up out of the more simple sugars and starches, some of which can be resolved again into sugars and so act as fuel in the body. But cellulose, which is a universal constituent of plant tissues, is not directly available as food, since animals possess no enzyme that will resolve cellulose into sugars. The cellulose derivatives which form the tissues and woody fibre of plants are also unavailable as food, except through the agency of micro-organisms in the digestive tract of certain classes of animals.

The fats and oils are equally fuel, but more concentrated, so that weight for weight they will furnish

more than twice as much energy as the carbohydrates. The proteins possess value as fuel, indeed they supply as much energy as an equal weight of carbohydrate, but their essential function is to build up the flesh of animals and to repair the constant wastage of the cells. Proteins are thus complete foods in a way carbohydrates and fats are not, and the bodily machine could run on proteins alone. Besides their carbon and nitrogen proteins also contain some sulphur and phosphorus which are required in tissue building but eventually get excreted in the fæces and urine.

Finally, the food has to supply mineral substances for the body ; the bones, for example, possess a framework of phosphate of lime ; common salt is needed, since from it the hydrochloric acid of the gastric juice has to be made ; the blood and the cells contain such elements as phosphorus and sulphur, potassium, magnesium, calcium and iron, just the elements that are found in the ash of plants.

The body may thus be likened to a machine which has to be furnished with fuel in proportion to its output of work, and with proteins and minerals as material out of which the working parts can be kept in constant repair.

We can calculate the amount of fuel and of repair material required from the weight of the body and the amount of external work it is set to do, just as we make a similar calculation for a steam engine. But the living processes of an animal are by no means so simple as the operations of a steam engine. A long series of investigations, mostly belonging to the present century, have made it clear that the animal machine cannot work without certain other substances in very small quantities. It has been found, for example, that

animals cannot grow, but become disabled and eventually die, when they are fed with a carefully balanced diet of pure fat, carbohydrate, protein and minerals only. They can, however, make full use of such a diet if they are supplied with a comparatively minute quantity of certain materials contained in living plants and animals, of milk for example, though the amount is trifling compared to total amount of energy and tissue repair material in the rest of the food. These substances are called vitamins, and as yet we understand very little of how they function in the body. But if we return to the comparison of the body with a steam or petrol engine, we may liken the vitamins to the lubricating oil without which the machine will soon cease to run however ample the fuel supply. The vitamins are essential to the health and growth of man and animals, and the study of nutrition must constantly take them into account, though the major function of the food is to supply energy and repair tissue wastage.

The processes by which an animal deals with its food so as to liberate the stored energy begin with digestion; by this means compounds that still carry the energy get into the blood stream and thereby reach the cells in which the actual transformations of energy and material take place.

These processes are essentially the same in man and the other higher animals; though certain modifications of organs and function occur in the different animal groups they need not prevent us from considering the nutrition of men and the domestic animals jointly. The process of digestion involves getting the food materials into the blood stream, which means that they must either become soluble or reach that state of minute subdivision that will enable them to pass

through membranes. These changes are effected by enzymes, that class of substances which have already been described as existing in the plant, where for example they transform insoluble starch into soluble sugars and proteins into their constituent amino-acids. In animals we find various glands whose function is to secrete particular enzymes and cause them to mix with the food at the appropriate point.

The enzymes that take part in animal digestion belong to three groups, the amylases, proteases and lipases. The amylases attack starch and some of the kindred carbohydrates and by adding to it water, resolve it into the soluble carbohydrates—the sugars. Some of the amylases are only active in an acid medium and others require an alkaline one; they produce different sugars, which in their simplest form are soluble and utilizable by the animal. Animals, however, only store carbohydrates as such to a very limited extent, i.e. a special one called glycogen found in the liver and the muscles. The function of the proteases is to resolve the proteins by successive stages into the amino-acids out of which proteins are built up; again, some of them work in acid and others in alkaline solution. In the structure of the individual proteins different amino-acids enter, so that it is not entirely indifferent to the animal which class of protein it receives. The animal has to reconstruct its particular proteins, in the flesh for example, out of the amino-acids that are in the blood stream, and it has therefore to pick out the right raw materials in the proper proportions. Gowland Hopkins found that rats would not survive on a pure diet in which the only protein supplied was zein from maize. If, however, a small supplement of an amino-acid called tryptophane was

added to the zein-containing diet the rats could make use of the zein. Analysis then showed that zein lacks the tryptophane group, which is an essential material in the construction of the complex body proteins. The reconstruction processes by which proteins are built up afresh out of the amino-acids is doubtless due to the intervention of enzymes.

Just as the proteases break down proteins, the lipases break down fats into their constituent fatty acids and glycerin, all soluble substances. From them the animal reconstructs different fats, again selecting the particular fatty acids it requires from the mixture resulting from the vegetable fats. Sometimes the animal does very little reconstruction and the constituents of the fat in the food can be recognized in the animal's milk and body fat. The animal has, however, some power of constructing fat, because it can manufacture fat when the food contains carbohydrates and proteins only without any fat.

The diagram, Fig. 1, shows in crude outline the digestive tract of a human being. The food is masticated in the mouth and is thereby mixed with the saliva, excreted by the glands in the cheeks and under the tongue. The saliva contains an enzyme, ptyalin, that converts starch into sugar as long as the medium is neutral or alkaline. When the food passes into the stomach, cells in the walls of the stomach secrete gastric juice, which contains a protein-splitting enzyme called pepsin and also hydrochloric acid. The pepsin is active only in acid solutions, but as the gastric juice gets mixed with the food the acid suspends the action of the ptyalin of the saliva. By degrees the food is passed into the duodenum ; on its way it receives bile from the gall-bladder and in the duodenum itself it

is mixed with the pancreatic juice. The bile contains certain salts which assist to emulsify the fats, i.e. to convert them into minute droplets. The bile also assists the work of the pancreatic juice, the enzymes of

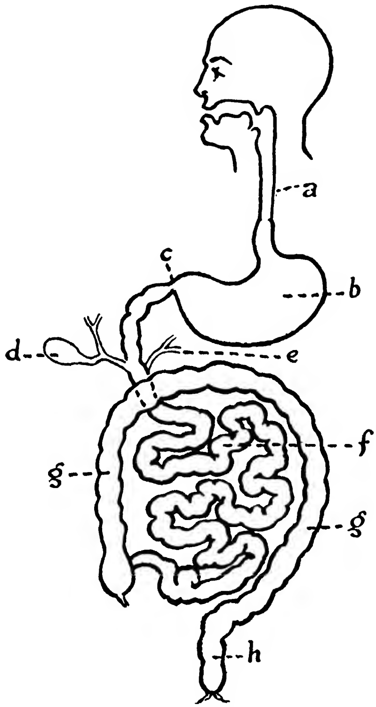

FIG. 1.—DIAGRAM OF HUMAN DIGESTIVE TRACT.

(*a*) Œsophagus or gullet ; (*b*) Stomach ; (*c*) Pylorus ; (*d*) Gall-bladder ; (*e*) Duct from pancreas ; (*f*) Small intestine ; (*g*) Colon or large intestine ; (*h*) Rectum.

which are active in an alkaline medium. But the pancreatic juice also contains a starch-converting enzyme and the precursor of a new protein-splitting enzyme called trypsin, as well as a lipase which splits

up the fats, now more accessible because they have been emulsified, into their constituent fatty acids and glycerin. The food then enters the rest of the small intestine where the digestive process is continued, new enzymes being added together with another body which activates the trypsin of the pancreatic juice. The walls of the small intestine are furnished with an immense absorbing surface, the villi, through which the dissolved sugars and amino-acids pass into the capillary blood-vessels and so into the blood stream. The villi contain also a central tube called a lacteal which gathers up the fatty acids and other products of the fat digestion and passes them into the lymphatic system by which they eventually reach the veins. Thus the whole of the digested food eventually reaches the blood stream in a soluble form for utilization by the appropriate cells of the body. The undigested remains of the food together with the waste products from the bile pass in the large intestine, where they lose a good deal of water with which they were mixed and are passed along to be excreted as the fæces.

Without going into the details of structure and physiology the blood stream feeds the living cells and receives their waste products ; as it passes through the liver the nitrogen compounds are broken down to urea, which is finally excreted by the kidneys.

Some of the domestic animals, as the pig, the dog, and even the horse, possess digestive apparatus not dissimilar to that of man, but herbivorous animals, and particularly the ruminants, display adaptations designed to enable them to deal more effectively with bulky vegetable foods.

Animals which chew the cud, like cattle and sheep, are characterized by the possession of a large organ,

the rumen or paunch (see Fig. 2), into which the food passes directly after some mastication in the mouth and mixture with saliva. The food is churned about in the rumen, where not only does the saliva begin its action, but a certain amount of digestion of cellulose takes place, partly due to cellulose dissolving ferments in the food itself, partly to the action of bacteria. The second receptacle, the reticulum, acts as an extension of the rumen. When the animal is at rest

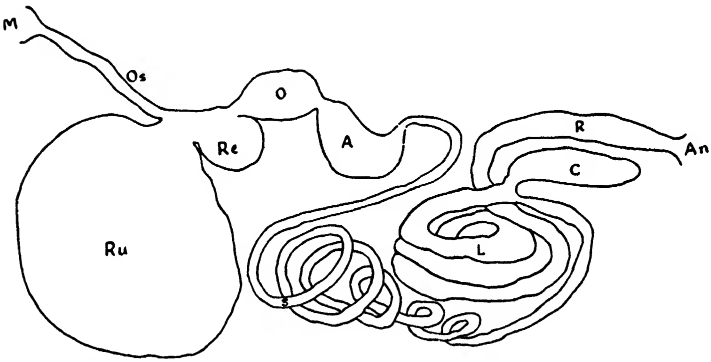

Fig. 2.—Diagram of Digestive Tract of a Ruminant.

M, Mouth; Os, Œsophagus; Ru, Rumen; Rt, Reticulum; O, Omasmum; A, Abomasmum; S, Small intestine; C, Cæcum; L, Large intestine; R, Rectum; An, Anus.

after feeding and begins to chew the cud, boluses of the food are regurgitated into the œsophagus and back into the mouth, where they are chewed afresh and mixed with more saliva. The food is again swallowed, but a sorting takes place and only the finer portions are passed into the omasmum or third stomach; the coarser portions return to the rumen. In the omasmum the churning actions of the rumen are continued and only material that has been worked down

to a fine condition is allowed to pass on to the abomasmum, the true digestive stomach, where it meets with the ferments of the gastric juice.

In the small intestine the digestive processes are continued after the entry of the bile and the pancreatic juice followed by the *succus entericus* which is secreted by glands situated in the small intestine itself and adds various sugar ferments, erepsin (a protease), and enterokinase that activates the trypsin-containing body, which with an amylase and a lipase had been supplied in the pancreatic juice.

In the large intestine, including the cæcum or blind stomach—an organ which has been reduced to a rudiment almost in man but is specially large in the horse—the partly digested food begins to be further attacked by various groups of bacteria, with the formation of soluble substances which pass into the blood and can be utilized by the animal. For example, cellulose and kindred compounds in fibre are to some extent converted into sugars. In consequence, what is roughly called fibre in a food like hay, possesses some value to cattle, sheep and horses, but little or none to pigs, which possess a comparatively simple digestive tract.

It now remains to assess the value of these food constituents in terms of energy. For that purpose the unit employed is the Calorie, the amount of heat that is required to raise the temperature of a kilogram of water by one degree Centigrade. Though this is a measure of heat alone it is convertible into the similar measuring units of all other forms of energy, such as mechanical work, electricity or light. For example, the Calorie is equivalent to the work required to lift 425 kilograms by one metre (or 1·4 tons 1 foot), and we can thus estimate the energy contained in a ton

of coal, and therefore the work that might be got out of it, when we have once determined by experiment how many Calories 1 lb. of the coal will give out in burning. Similarly, coal gas is now sold on its energy value, by British therms, one therm being the heat required to raise the temperature of 100,000 lb. of water by one degree Fahrenheit, equivalent to 251·9 Calories. This therm, for which the householder is charged, represents a certain number of cubic feet of gas which, when burnt, will give out that amount of heat.

We can therefore make a first estimate of the energy residing in any foodstuff by determining by experiment the amount of heat it will give out when burnt, i.e. its fuel value. This, however, by no means measures the energy obtainable from the food. Coal or charcoal, for example, have a very large fuel value but no food value, since neither can furnish the animal with any digestible material. Hay again, with a considerable fuel value, is so little digestible by human beings that it would not keep the body warm, but is so much more digestible by cattle that they can live on it through the winter.

In order, then, to determine the energy or heat value to the animal of any food it is necessary to deduct from its full value whatever amount of energy is still contained in the portions of that food which are not burnt up in the animal. For example, of a mixed food a proportion will be indigestible and excreted in the fæces, so the fæces must be burnt in their turn so as to determine the amount they contain of energy unused by the animal. Again, the nitrogen in the proteins of the food is excreted as urea, which also will give out heat when burned, so another

deduction must be made for the fuel value of the urine derived from the food.

Lastly, in the case of herbivorous animals the bacterial attack on the carbohydrates to which allusion was made earlier (p. 11) results in the production of a certain amount of methane or marsh gas. As this escapes from the body unburnt it constitutes another source of loss.

Sugar and the digestible carbohydrates like starch liberate on burning about 4·1 Calories per gramme, and since with man there is no loss through production of marsh gas we may give a value of a little more than 4 to all the carbohydrates that are digested in a given food. With herbivorous animals, because of the losses as methane, we cannot give to starch and its related carbohydrates a much larger value than 3·7.

Fats and oils have a higher fuel value, the burning of one gramme gives out nearly 9 Calories, and as there are no waste products in the utilization of the fats, their heat value to the animal is the same as their fuel value, more than twice that of the carbohydrates. Of course, the many different fats, like the various carbohydrates, do not all possess exactly the same fuel value, but for the purposes of rationing it is accurate enough to use the approximate average values that have been given, because the natural variation in all the elements of the problem is so large as to render these minor differences negligible.

The fuel value of protein is about 5·8 as compared with 4·1 for carbohydrates, but as the resulting urine will still contain 1·1 units of energy we can only reckon 4·7 Calories as the heat value to the animal of the gramme of protein. Protein is thus rather more efficient than carbohydrate as a furnisher of energy,

and more than half as efficient as fat, but in addition it has its own special value as the source of the nitrogen compounds required for tissue repair.

Of course, it must not be supposed that all of the heat values to the animal thus measured are simply translatable into work at the ratio given, i.e. 1·4 foot tons per Calorie. The animal is a machine like any other and it has not been possible to construct any machine that is perfectly efficient, i.e. that is capable of transforming into work all the heat energy it receives. The most efficient steam engine only transforms about one-sixth of the energy it receives from its fuel into useful work. A horse, however, has been able to transform from one-fourth to one-third of the energy of the food it receives for work into work performed, though since the horse must also receive energy for its own bodily functions its gross efficiency is somewhat less than that of the steam engine. Since energy cannot be destroyed, we have to look somewhere for the balance not transformed into work, and we always find the waste energy has passed into low-grade heat. In the steam engine there are the various losses by leakage, by friction, which again generates heat in the rubbing parts, and in the heat of the escaping combustion gases and waste steam. In the animal there is a continual loss of bodily heat, which represents all the energy of the food consumed except that which is stored as fat or flesh in the body or is spent in doing work outside the body. Of course there are internal motions like breathing and the circulation of the blood which have to be driven by the energy of the food, but the work thus done is eventually transformed into bodily heat.

CHAPTER II

ENERGY REQUIRED FOR MAINTENANCE

Experimental determination of Digestibility. The Calcrimeter. Intake and Output of Carbon and Nitrogen. Energy required to keep the Animal Machine running. Energy spent in Digestion. Energy required for internal work is evolved as Bodily Heat. Margin available for Increase or External Work. Lower-grade Foods available for Maintenance. Loss of Bodily Heat proportional to Surface

IN the preceding chapter the fundamental basis of nutrition has been outlined—that food consists of certain compounds of carbon which supply energy to the organism by their combustion with the oxygen contained in the air breathed into the lungs. Other carbon compounds containing nitrogen supply material to repair the waste of tissues and to build up flesh. These are the major elements of nutrition. Since these compounds are mostly insoluble in water and yet have to enter the blood stream they have first to undergo the process of digestion, their solution being brought about by various enzymes which are secreted by particular organs in the body. A measure of the energy contained in foods is furnished by the heat they will evolve when burnt, though there must be deducted the heat evolved on burning the undigested portions of the food and other waste products excreted

from the body. The complete food story must also take into account the mineral salts required by the body and the small quantities of certain substances classed together as vitamins, without which the major elements of food cannot properly be utilized.

While all these factors of nutrition are essential we must still regard the exchanges of energy within the body as of prime importance and it will make them more intelligible if the method by which they are experimentally determined is outlined. In order to determine the digestibility of a given food it is necessary to compare over a period of some days the amount and composition of the material fed with the amount and composition of the fæces voided. For example, the animal is brought into a stable condition on a diet that will maintain it in health and both the daily output and the composition of the fæces are determined. An addition is then made to the diet of a specified amount of the food to be tested and this is maintained for ten days or a fortnight, during which time the fæces are collected and analysed. A comparison can then be instituted between the daily output of fæcal matter before and after adding the specified food, and the analyses will show what proportion of the carbohydrates, fats, and proteins consumed in the food were utilized by the animal or passed through it. Thus are determined the digestibility co-efficients of Table II, p. 76, though they will not be the same for all classes of animals. Cattle and sheep, with their more extensive digestive systems, deal more thoroughly than pigs or horses with coarse foods containing much fibre.

But to determine the complete history of the food and the energy exchanges that are involved a much more complicated experiment is necessary. The

animal has to be enclosed in a chamber through which a measured current of air is passing. The entering and leaving air is continuously sampled and analysed, so that over the period of the experiment an exact measure is obtained of the oxygen used and of the carbon dioxide and water vapour exhaled by the animal. It is also necessary to know how much methane is being exhaled in the air that leaves the chamber. A stream of water at a fixed temperature circulates through a coil of pipes surrounding the chamber so as to carry off all the heat evolved by the animal and maintain the temperature of the chamber unchanged throughout the period of the experiment. The volume of this water and its temperature is continuously recorded whereby a measure of the largest item in the heat evolved is obtained. The air as it issues is also warmer than when it entered, and as its volume and temperature are also continuously recorded, the amount of heat thus evolved can be determined. A further correction has to be made for the heat that has been used in converting water in the animal into the water vapour present in the issuing air, but the sum of the heat contained in the circulating water, the expired air and water vapour, gives the total heat evolved by the animal. By suitable attachments the daily output of urine and fæces is collected for analysis and comparison with the food ration. The experiment involves many elaborations because it has to be carried on for a considerable period, but it does provide all the data for a sort of balance sheet both of the materials and the energy fed to the animal. The carbon in the food, less that excreted in the urine, fæces and methane, represents the carbon utilized by the animal, and if then from that is deducted the carbon

in the exhaled carbon dioxide, the carbon retained by the animal as fat is determined. On the other hand, the animal may have lost weight during the experiment, in which case the carbon dioxide exhaled will be in excess of the net intake. Similarly, a nitrogen balance is obtained between the nitrogen in the food consumed and that excreted in urine and fæces. For the energy balance the fuel value of the food consumed less the fuel value of urine, fæces and methane will be equal to the total heat evolved as measured, plus or minus energy stored in the animal as weight lost or gained. This last figure can be exactly calculated together with the amount of carbon and nitrogen retained and lost by the animal.

In such a series of experiments it is possible to get an adult animal into as nearly as possible a stationary condition, neither gaining nor losing in weight, the intake and excretion of both carbon and nitrogen being balanced. What then is the digested portion of the food being used for if the animal is not putting on weight nor doing any work? The living animal is, however, always at work even when it is sleeping, just as there is some consumption of fuel when a motor-car is only idly ticking over. In the first place the animal has to breathe and the blood has to be driven round the body: energy is required to effect these muscular motions as also other involuntary and voluntary movements of the body. This energy is derived from the combustion in the muscles of sugars drawn from the blood stream and is attended by the evolution of a definite amount of heat. Again, the digestive process itself involves a certain amount of work in the peristaltic motion of the intestines and so on, and foods in which the digestible materials are

locked up in a considerable body of fibrous tissue may require a good deal of work before the digestive enzymes obtain access to them. If, indeed, the work spent in the digestion of a given food is very large, it may approach or even exceed the heat value of the digested portion, and so leave no margin for either the internal or external work of the body. Of course the energy thus spent either in digestion or internal work is still transformed into heat, whereby the animal is kept warm ; hence an animal at rest on a maintenance diet, the heat value of which just supplies enough energy for both digestion and internal work, will still maintain its animal heat, and will even be able to increase it by a greater consumption of food if it is forced to make up for greater losses of heat by being put to live under colder conditions. But if all the energy derivable from the food is spent in effecting digestion and internal work, there will be no margin left for external work or the production of increased weight. In such a case, however much food the animal eats, it can never do any work nor grow any heavier. This condition, when the energy derived from the food is wholly or even more than balanced by the energy required for digestion, is realized in the case of a horse feeding upon straw, which is very fibrous, so that the work required is great and a large proportion remains undigested. Zuntz found that the horse actually consumes more energy in digesting straw than is contained in the portion digested, and this was confirmed by an experiment of Müntz, who fed a horse on straw alone. Although the horse was allowed an unlimited amount of straw, it died at the end of about two months, thoroughly exhausted, because it had been compelled to draw upon its body.

Again, Kellner, in experiments with oxen, which are better able than horses to deal with foods like straw, found that more than four-fifths of the energy contained in the digested part of the straw was consumed in the digestive processes, leaving less than one-fifth available for work or increase. When, however, the straw was made into a pulp by the processes employed by paper-makers, who disintegrate the cellulose by boiling with an alkali under pressure, as much as 88 per cent. was digested, and of this digestible matter a little more than a third only was consumed in effecting digestion.

This leads us to perhaps the most important consideration in the theory of nutrition—that foodstuffs, after the indigestible portion has been deducted and after the work the animal must spend upon them in order to digest them has also been deducted, possess as a rule a margin of energy remaining which can either be put into the bodily machine in order to do external work or is available for storage in the body as fat or flesh. This margin determines, in fact, the usefulness of the feeding stuff to the farmer, i.e. what it can do in enabling the animal to put on weight or to do work, if for example it is a horse or a work ox. This margin we call the net energy.

Bearing in mind these principles, we may trace certain simple practical consequences. Rough, coarse fodders like hay or straw, poor grass, roots, etc., serve perfectly well for keeping animals in store condition, for though they require a considerable expenditure of energy for their digestion there is enough margin to carry on the internal work of the body and the whole energy is afterwards available as heat. The animal has only to be kept warm and is neither working nor

increasing in weight. Similarly, animals that are at slow work and are never called upon for any great output of energy in proportion to their weight, can be fed upon bulky low-grade fodders which do not develop any great surplus of energy. But when animals are growing rapidly or are performing heavy and rapid work, then comparatively rich and concentrated foods are necessary, foods which develop a large surplus of energy over that which is required for their digestion. A horse standing in the stable may be fed on nothing but hay, just as a horse out at grass needs only a little hay besides the old grass, even in severe winters, but as soon as the horse is worked, instead of more hay it must be given corn of some kind; and a racehorse, on which great calls are made for a sudden and excessive output of energy, must have the most concentrated and digestible foods that can be obtained. No increase in the amount of the lower-grade foods will compensate for their lack of concentration, because so much time would be spent by the animal in gathering up the necessary surplus energy. To take another example, cattle or sheep will never grow fat in one season on the grass growing on the majority of fields, however great an area they may be given to graze; it is only on certain choice fattening pastures that the increase is rapid enough to prepare an animal for market without artificial assistance. On the poor pastures the animal either does so much work in collecting its food or spends so much of the energy obtained from its food in digesting it, that the surplus left for production does not permit of rapid growth. On the fattening fields the grass possesses a smaller proportion of fibre, and therefore less of its heat value is wasted in the digestive processes.

Similarly, in the last stages of fattening animals in stalls carbohydrates are of much less value than they are at an earlier period, because they call for an expenditure of energy in digestion which is disproportionate to the increase they produce at that stage, when the increase bears a very small ratio to the food consumed, whereas much less of the energy of fats and proteins is wasted in the digestion process.

This leads us to another useful conception in the theory of nutrition ; for every animal there will be a maintenance ration which will just maintain the animal at a constant weight, neither increasing nor diminishing, and will supply it with as much energy as it requires for its average activities when at rest. This maintenance ration is a sort of datum line ; for any further work or movement beyond the minimum, or for any increase of weight and production of milk, more food must be supplied and that in exact proportion to the work and production demanded.

In any scheme of rationing on scientific lines the maintenance ration is the first thing to be ascertained for the animals in question, then the productive ration can be added in accordance with the amount of production expected. In this connection there is another point to be considered ; though the maintenance ration may be made up of comparatively low-grade food it is necessary to bear in mind that the stomach of all animals, but particularly of the horse and pig, is limited in capacity, and if it is kept too fully occupied with coarse fodders for the maintenance ration there may be insufficient room for a productive ration that will yield optimum increase. Leaving this factor out of account for the moment, on most diets, even maintenance rations, the energy required by the resting

animal to maintain its temperature is greater than that required for internal work ; some of the food is burnt simply and solely as fuel for warming, and the amount of food required will be determined only by the heat lost by the animal. The magnitude of this factor will vary with the size of the animal, or rather with the surface it possesses, because heat is lost only from the surface. Now the smaller the animal the greater is its surface in proportion to its weight (a cubic foot has a surface of 6 square feet ; a cube of the same material but 2 feet on the side would weigh eight times as much, but only have a surface of 24 square feet, i.e. four times as much as before) ; hence small animals will require for maintenance more food in proportion to their weight than large ones. Of course, the greater the difference in temperature between the animal and its surrounding air the greater will be the loss of heat and the consumption of food to repair the loss ; hence the truth of the old saying that shelter is as good as a meal. Heat may also be required, and in consequence food will have to be consumed, in raising the temperature of the food and water to the body temperature, and this may be considerable when large quantities of very cold water, or roots which contain nearly 90 per cent. of water, are consumed at a freezing temperature. These considerations, however, only apply to animals on a maintenance ration when the food is reduced to the minimum necessary to keep the animals warm ; on fattening rations there is always a surplus of heat that cannot be utilized in any other way.

The actual maintenance ration will vary with the kind of animal, with its weight and the extent of surface it exposes to loss of heat. A fat bullock

weighing about 1,750 lb. requires about 20,000 Calories heat value in its digested daily food in order to keep it going. The maintenance requirements of a horse are very similar to those of a bullock ; according to Zuntz, the maintenance ration of a horse at rest must evolve about 12,100 Calories per diem, and not more than two-thirds of this energy must be expended in the work of digestion. Sheep have rather greater requirements in proportion to their weight, because of their smaller size and therefore larger proportional surface, and also because of their higher temperature ; a sheep weighing 100 lb. requires digestible food which will develop about 2,000 Calories, i.e. 1,000 lb. of sheep require 20,000 Calories, whereas 1,000 lb. of lean cattle only require about 11,000 Calories. All these figures, however, refer only to maintenance diets, when the animal is doing no work and not putting on flesh.

CHAPTER III

THE PRODUCTIVE RATION

Thaer's Hay Values of Foods. Gross digestible Energy. Experimental determination of Net Energy available for Production. Kellner's experimental determination of requirement for Increase. Starch Equivalents. Comparison of Starch Equivalents with Net Energy

AT an early stage in the study of the nutrition of animals attempts were made to obtain some sort of food unit whereby to measure, or at least to compare, the value of the different cattle foods. More than a century ago, for example, Thaer, a German experimenter, attempted to estimate "hay equivalents" by finding how much of the food would produce the same growth in the animal as 10 lb. of hay.

Hay with its variability and its large content of fibre is obviously a poor substance to take as standard, and it is simpler and more scientific to consider the amount of energy obtainable from the food. Of course, no single number can represent the value of the food, since both the energy it will supply and the protein have to be taken into account and are independent one of another. It has already been pointed out that the value of the food is not measured by the heat it will give out when burnt, but that deductions have to be made for the energy still remaining in the excreta—urine, fæces and gases. Again, energy that

is spent in the act of digestion, though it provides heat to keep the animal warm, equally cannot be used by the animal for production or work, consequently it must also be deducted in order to arrive at the useful, productive or net energy available from the food.

It is, of course, simple enough to calculate from the analysis of a feeding stuff the gross digestible energy it can supply. One gramme of protein produces on combustion 5·8 Calories, from which must be deducted 1·1 Calories left unburnt in the urea ; one gramme of pure fat produces 9·3 Calories, but it is customary to

	Percentage.	Factors.	Calories produced in Body.
Protein	41	4·7	192·7
Fat	9	8·5	79·2
Carbohydrate and digestible fibre .	26	3·76	97·7
			369·6 or 3·696 per gramme

deduct 0·5 for the impurities reckoned in the crude fat ; one gramme of carbohydrate produces 4·1 Calories, but in the animal we must deduct 0·4 for the energy lost as methane ; digestible fibre is treated as carbohydrate. Thus we get factors of 4·7, 8·8 and 3·7 for protein, fat, carbohydrates and digestible fibre, and we can take an analysis such as that of gluten meal above and calculate in Calories the gross or metabolizable energy the gramme of the food can liberate in the body. How much of that energy the food will require for the work of digestion leaving the balance available for production and work can only be deter-

mined by experiment and will vary with the food and to some extent with the animal consuming it.

By a large series of experiments in the calorimeter Armsby and his colleagues in Philadelphia determined what they call the net energy of many of the feeding stuffs, i.e. the energy available for production and work after all deductions for waste and work spent in digestion have been made. For example, an animal fed on a given ration (below the maintenance level) was found to be losing a given number of Calories a day in excess of the gross metabolizable energy the ration could furnish. These excess Calories must therefore have been derived from burning up some of the body fat of the animal. A known amount of the food under investigation was then added to the former ration whereupon the total output of heat as measured in the calorimeter was increased, but when the gross energy the new ration could furnish was deducted, it was seen that a smaller amount was being supplied by the body than in the former experiment. The difference between the number of Calories the body had to supply, with and without the added food, is clearly enough the equivalent in Calories of so much fat from the body and therefore the measure of the net or productive energy of the food.

Armsby's results are expressed in terms of net energy per 100 lb. of the food.

	Net energy in Calories per lb.
Wheat	916·6
Barley	899·4
Maize	840·0
Beans	732·9
Oats	675·6
Clover hay	356·8

Similar conclusions to those of Armsby were reached by Kellner working by a different method. Kellner put his animal in a respiration chamber, in which the air entering and leaving was measured and analysed, thus determining the amount of carbon dioxide and methane excreted by the animal. Fæces and urine were collected and analysed, in fact the apparatus differed only from Armsby's calorimeter in that the heat evolved by the animal was not measured. But the respiration chamber supplies all the data for drawing up a balance sheet as regards the fate of the carbon and nitrogen of the food. Let us suppose that under such conditions Kellner arrived at a ration of hay that would just keep the experimental steer in a level condition, neither gaining nor losing either carbon or nitrogen. To this maintenance ration he added a definite quantity of pure starch, 1 lb., 2 lb., 4 lb., as the case might be ; on making out his balance sheet again a certain amount of carbon was always found to have been retained by the animal, not quite one-fifth of a pound of carbon for each pound of starch added to the maintenance ration. Now this carbon must have been stored in the animal as fat, and since fat contains about 77 per cent. of carbon, it is clear that one pound of starch has produced one quarter of a pound of fat.

By a series of experiments upon this principle Kellner arrived at the following quantities of pure food constituents that were required to make 1 lb. of fat in the animal, i.e. 4·25 lb. of protein, 1·67 lb. of fat, and 4 lb. of carbohydrate, or conversely 1 lb. of the pure constituent would yield respectively 0·235, 0·6, and 0·25 of fat. It will be noted that the quantity of energy stored is only a fraction of the available energy in the food,

even of pure fat consumed by an animal also supplied with a maintenance ration only two-thirds is retained.

Taking these data for the pure constituents, we can calculate what increase of fat a given mixed feeding stuff might be expected to give. Thus for linseed cake we get the following on multiplying the second by the third column :

	Per cent. in Food.	Digestible.	Factor for Fat Production.	Fat per 100 lb.
Protein	29·4	25·3	0·235	5·95
Fat	9·2	8·7	0·6	5·22
Carbohydrate . .	36·6	33·0	0·25	8·25
Fibre	9·0	—	—	—
				19·42

The experimental figure was 18·84 lb. of fat put on for 100 lb. of the linseed cake fed, a deficiency of 3 per cent. as compared with the calculated figure of 19·42. That this deficiency was not due to experimental error is seen from the fact that similar deficiencies are exhibited by all the foods investigated and become greater the larger is the proportion of fibre in the food, rising to over 50 per cent. for such materials as poor hay or straw. The deficiency, in fact, is due to the energy spent on the internal work of digestion, and the final figure that Kellner obtained for the productive efficiency of linseed cake is equivalent to the net energy of Armsby's tables. Kellner arrived experimentally at a series of percentages representing these deficiencies in the fat stored after the consumption of various types of food, as compared with what the same digestible constituents would have given if

fed in the pure state, ranging from the 3 per cent. for linseed cake to 57 per cent. for oat straw. He was then able to make a correlation between the proportion of fibre the food contained and the deduction to be made for the internal work spent in digestion, whereby the net energy can be calculated from the analysis. He adopted, further, a new mode of expressing these results ; instead of stating them as net energy or fat produced per lb. of food, he made a comparison of the value of the food for production as compared with that of pure starch. Thus 100 lb. of linseed cake produced 18·84 lb. of fat, and 4 lb. of starch are needed to produce 1 lb. of fat, therefore $18{\cdot}84 \times 4 = 75{\cdot}36$ lb. of starch will produce as much increase in the animal as 100 lb. of linseed cake, and the *starch equivalent* of the linseed cake is 75·36.

Kellner's starch equivalents may be compared with Armsby's net energy on the basis that 1 lb. of starch in the animal produces $\frac{1}{4}$ lb. of fat, which is equivalent to 1,070 Calories. Hence, if starch equivalents are multiplied by 1,070, we should get Armsby's net energy in Calories. Actually the agreement is good enough to demonstrate the correctness of the principles upon which both sets of figures are based ; the agreement was not exact because the two experimenters were dealing with different foodstuffs, American and German, and not strictly comparable animals. A margin of error of this kind indeed extends to all calculations relating to the nutrition of animals ; compositions vary, and properly speaking a different set both of digestibility and of productivity coefficients are needed for each class of animal—cattle, sheep, pigs, horses and poultry. We can illustrate the successive steps in the energy exchanges in the diagram, Fig. 3.

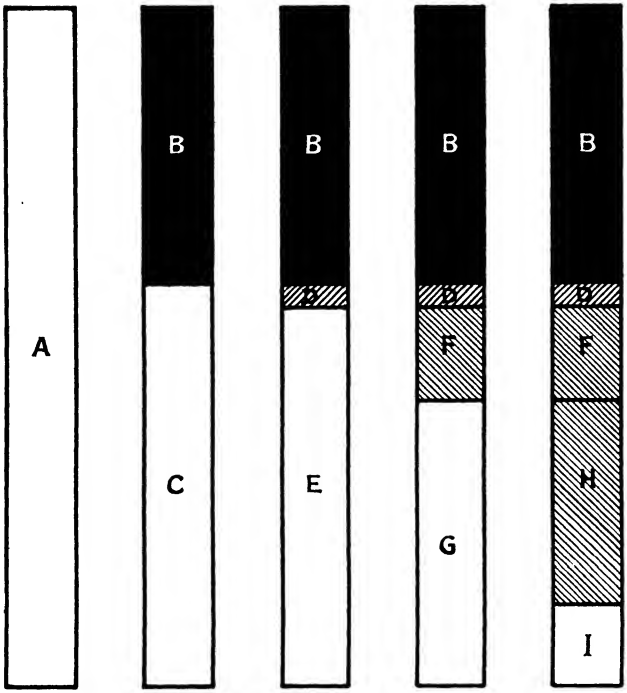

FIG. 3.—DIAGRAM SHOWING EXCHANGES OF ENERGY DURING FEEDING OF MEADOW HAY.

A. Fuel value of food.
B. Fuel value of undigested fæces.
C. Fuel value of digestibles.
D. Fuel value of urea and methane excreted.
E. Gross digestible energy.
F. Work required for digestion, etc. (= Bodily Heat).
G. Net energy for production (= Starch Equivalent).
H. Heat evolved in conversion (= Bodily Heat).
I. Increase as fat or external work.

Starch equivalents form the most convenient means of summing up the productive power of any feeding stuff and of calculating the composition of rations. The starch equivalents of all the usual feeding stuffs are set out every month in the *Journal of the Ministry*

of Agriculture, a selection from which is here given as Table I.

	Price per ton.	Protein Equivalent.	Starch Equivalent.	Manurial value per ton.	Price per unit of Starch Equivalent.
	s.			*s.*	*s. d.*
Wheat . . .	95	9·0	72	8	2 3
Barley	115	6·2	71	8	1 10
Oats	120	7·6	60	9	2 3
Maize	98	7·6	78	7	1 4
Beans	110	19·7	66	16	1 8
Weatings . . .	102	10·7	56	13	2 4
Linseed Cake (9%)	177	24·6	74	20	2 2
Cotton Cake (Dec.)	132	34·7	68	28	2 0
Palm Kernel Cake	117	16·9	73	12	1 8
Dried Beet Pulp .	105	5·2	66	5	1 6

It is evident, however, that the starch equivalent alone does not express the whole value of the feeding stuff because it does not take into account the protein content ; methods of valuation into which both factors enter will be discussed later (p. 81).

CHAPTER IV

FEEDING FOR PRODUCTION

Slaughter Method to determine composition of Animal at Successive Stages of Growth. The Respiration Chamber. Maintenance Ration proportional to the Square of the Cube Root of Weight. Maintenance Rations and Factors for increase of various Farm Animals

HAVING thus arrived at a definition of the various constituents of the food and the changes which they undergo in the animal, it still remains to study the growth of the animal and its requirements at successive stages. The earliest experiments on the subject which laid the foundations of our knowledge of the nutrition of the animal were those carried out by the method of comparative slaughter. A number of young animals are selected as uniform as possible; one of them is killed, after which its carcase is dissected as exactly as possible into its components—blood, fat, flesh, bones, etc. Each of these is dried and analysed for fat, nitrogen and ash, so that in the end a balance sheet can be drawn up showing the composition of the animal as regards water, fat, protein and ash and the location of each of these constituents. The remaining animals receive a fattening ration, the amount and composition of which is also determined. At regular intervals another animal is withdrawn for slaughter and analysis, ending with a fully grown

animal in prime condition for the butcher. This method of experiment is extremely laborious, so that it can only be applied to a small number of animals; in consequence it is subject to errors due to the inherent differences in the animals in the group, errors which could only be minimized by repetition on an impracticable scale. But on the assumption that the animals were fairly comparable in their rate and manner of growth it does give a picture, stage by stage, of what portions of the food were utilized by the animal for growth and how the character of that growth changes as the animal matures and fattens. Several very definite conclusions emerge, that the carbohydrates of the food can be converted into fat by the animal, which indeed need not receive any fat in its ration but can be fattened on carbohydrates and protein alone, however uneconomical such a procedure might be in practice. The experiments also show that the utilization of the food constituents decreases as growth and fattening proceed, the gains to the animal per pound of food consumed becoming smaller in the later stages. Particularly as regards protein the young growing animal might utilize and form flesh from as much as 25 per cent. of the protein fed, while in the final stages less than 5 per cent. would be retained. Again, it is found that in the last stages of fattening, when the live weight increase from day to day becomes small, the animal is really getting fat by the replacement of water in the body by fat.

The comparative slaughter method was too laborious to be repeated after Lawes and Gilbert's classic series of experiments, though latterly it has been resumed to a certain extent to settle some of the points that the methods of the respiration chamber and the calori-

meter leave uncertain. However, it is by these two latter methods of Kellner and Armsby that our knowledge of the conversion of the food constituents into flesh and fat has chiefly been determined ; indeed the figures now current for the starch equivalents of the standard feeding stuffs are mainly due to Armsby's work.

We have arrived at the conception that the feeding of an animal may be considered as made up of two processes—maintenance, which requires sufficient food to support the ordinary activities of the body and the loss of heat the body is always experiencing, and production, for which food is required above the maintenance ration, and is itself represented by the increase of live weight, or the milk yield, or the external work performed, as the case may be. It must not be supposed, however, that the whole of the starch equivalent in the productive ration is laid on as fat in the animal in the ratio of 1 of fat to 4 of starch equivalent. It is obvious that if the animal is overfed some of the food will not be utilized ; again, when the animal has reached or is nearing the fat condition, a smaller proportion of the starch equivalent will be utilized by the animal. It is also common experience that some animals in any bunch put up to fatten are "bad doers," and either fatten very slowly or may never reach prime condition. Either the food is imperfectly digested or the excess of the starch ingredient is burnt up and its energy evolved as bodily heat. T. B. Wood demonstrated that bad doers are characterized by a high skin temperature and thus are experiencing greater losses of heat. Starch equivalents are experimentally determined upon animals receiving an amount of food approximating to a maintenance

ration only, and therefore in a condition to make maximum use of the productive element of the ration.

The first step consists in ascertaining the maintenance ration for each animal. Now when an animal is at rest and has reached such a stable condition that it is not even doing work in digesting, the only output going on is the loss of bodily heat. The rate of loss will be determined on the one hand by the difference in temperature between the animal and the air outside, and on the other by the extent of surface the animal exposes. The latter factor only is special to the animal, so that we may conclude that the maintenance ration which has to supply this loss of bodily heat must be proportional to its surface. However, as a rule we know nothing about the area of animals' skin, but we do or can know its weight, and it is easy to see that among animals of the same kind their surfaces will bear to one another a relation expressed by the squares of the cube roots of their weights. (Think of two similar cubes of wood, one 2 inches, one 3 inches on the side. Their weights will be proportional to their volumes, i.e. $2^3 = 8 : 3^3 = 27$. Each cube has 6 sides, so that the total surface of one will be $6 \times 2^2 = 24$ sq. in., of the other $6 \times 3^3 = 54$ sq. in., a ratio of 24 : 54 or 4 : 9. Now work back from the weights 8 : 27 ; the cube roots are 2 : 3, which squared gives the ratio of the surfaces 4 : 9.)

Applying this rule if we have ascertained the maintenance ratio for, say, a steer weighing 1,000 lb., we can calculate what it should be for another steer of any given weight. The calculation is found to hold until it is applied to very young animals, e.g. pigs under 50 lb. live weight or cattle under 5 cwt. The maintenance ration will be expressed in pounds of starch

equivalent required per diem, say 6 lb. per day for a 9-cwt. steer, and if the animal is to be kept in a store condition with little more than its maintenance ration this can be of a low-grade type of food like hay or straw, because the energy spent in digestion will still be available to the animal as bodily heat. For the 9-cwt. steer it will only be necessary to provide that the fodder does supply a sufficient margin of gross energy to amount to the Calories in 6 lb. starch equivalent, without becoming too bulky for the animal to be able to digest it day by day. But when animals are being kept in store condition on a maintenance ration or something near it the question of temperature becomes important. Animals possess a certain power of adjustment to changes of temperature by withdrawing blood from the skin when the temperature falls, or by sending blood to the surface, and further by perspiration, in order to meet high surrounding temperatures. But there is a limit below which this adjustment does not work, actually about 20° Centigrade for a full-grown pig. A pig on a maintenance ration will lose heat equivalent to 5 per cent. of its maintenance ration for each degree Centigrade the temperature falls below 20°, and in consequence at low temperatures the maintenance ration would have to be correspondingly increased or the animal would lose weight. Actually pigs are very rarely fed as stores upon maintenance rations, and when extra food for production is being given there is a further supply of energy, that used in effecting digestion, which is added to the bodily heat. In constructing the pig's ration the question of temperature therefore enters little, however much from the physiological point of view it is desirable to keep pigs' quarters free

from chills and cold draughts. But sheep, young cattle and bullocks in the open under winter conditions may require extra food to balance the increased losses of heat.

The maintenance ration of steers varies from 4 lb. starch equivalent per day for a 5-cwt. calf to nearly 9 lb. for a heavy bullock of 16 cwt. The ration for a steer must also include from 1¼ to 1½ lb. of protein per day; then a further allowance of from 2 to 4 lb. starch equivalent for each pound of live weight increase. The high allowance of over 3 lb. holds for animals in the latter stages of fattening, when a good deal of the increase consists in the replacement of water in the carcase by fat without added weight, and again when the utilization of the starch equivalent is less. These data for steers can be brought together in a graph, Fig. 4.

Milch cows will require the same maintenance ration as steers of the same weight, which means about 5 lb. starch equivalent for a Jersey cow, nearly 6 for a Guernsey, and 6½ to 7 for a Shorthorn, with a protein requirement of from one-half to three-quarters of a pound. Then for each gallon of milk the cow is yielding there must be added 2½ lb. of starch equivalent, including 0·6 lb. of protein. For Jersey and Guernsey cows yielding milk with 4½ to 5 per cent. of butter fat these figures must be raised to 3 lb. starch equivalent and 0·7 lb. protein per day. These quantities refer in the main to cows kept indoors, when the amount and nature of their food can be definitely measured. But cows are out at pasture in many cases for the greater part of their productive life, in which case their rationing requires careful adjustment to the quality of the grazing and the milk yield of the cow. It may

be estimated that good pasture at the flush time of year is capable of supplying the maintenance ration and a productive surplus that will yield 4 gallons of milk per day, for each gallon above which the usual 2½ lb. starch equivalent will be required. As the season advances the feeding quality of the pasture falls off, by how much can only be guessed, but an ordinary

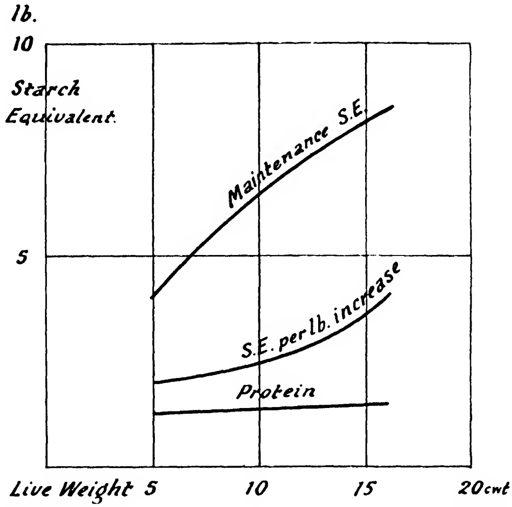

FIG. 4.—FOOD REQUIREMENTS PER DAY FOR FATTENING BULLOCKS OF 5 TO 15 CWT. LIVE WEIGHT.

poor pasture cannot be counted on to provide more than the maintenance ration plus starch equivalent for the production of one gallon of milk. Indeed, in hot dry weather when the pastures are burnt and flies are troublesome, cows may waste more energy in grazing than they can gain from the food they pick up, and they should only be turned out for an hour or two of exercise in the cool of the morning and evening.

Pigs after the weaning stage are usually brought indoors and fed so as to grow rapidly and reach a weight of 200 lb. at from six to seven months. As during this period their weight is increasing rapidly, so must the maintenance ration be raised, and by careful studies of the rate of growth of a Large White pig in the Cambridge calorimeter the late Professor T. B. Wood showed that the maintenance ration after following a more or less normal course began to increase very rapidly after a live weight of 200 lb. was reached. Delay in finishing heavy pigs and retaining them after they have reached the market weight is very wasteful, because the heavy maintenance ration keeps mounting up and for it no return is being earned. The maintenance ration for pigs varies then from about 1 lb. of starch equivalent for a 50-lb. pig to 2·4 lb. for a 200-lb. pig, rising to 2·8 lb. for a 300-lb. pig. The protein contained in the ration will be rising from 0·3 lb. to 0·6 lb. and to 0·7 lb. in the 300-lb. pig. At the same time the amount of starch equivalent required to produce 1 lb. of increase rises very steeply from about ½ lb. of starch equivalent at 50 lb. live weight to 2½ lb. at 300 lb. live weight. These relationships between live weight, and maintenance, increase and protein requirements are expressed in the graph, Fig. 5, adapted from T. B. Wood's figures.

The rationing of sheep presents more difficulties, both because of the variations in the nutritive value of the green fodder consumed and also because of some uncertainty attaching to the determinations of the maintenance ration for sheep. Taking T. B. Wood's figures, which are regarded by some investigators as high, a sheep of 100 lb. will require 9 lb. starch equivalent *per week*, including 0·4 lb. of digestible

protein. At this weight also the sheep will require 2 lb. starch equivalent for each pound of live weight increase and the protein required will rise to 1¾ lb. per week.

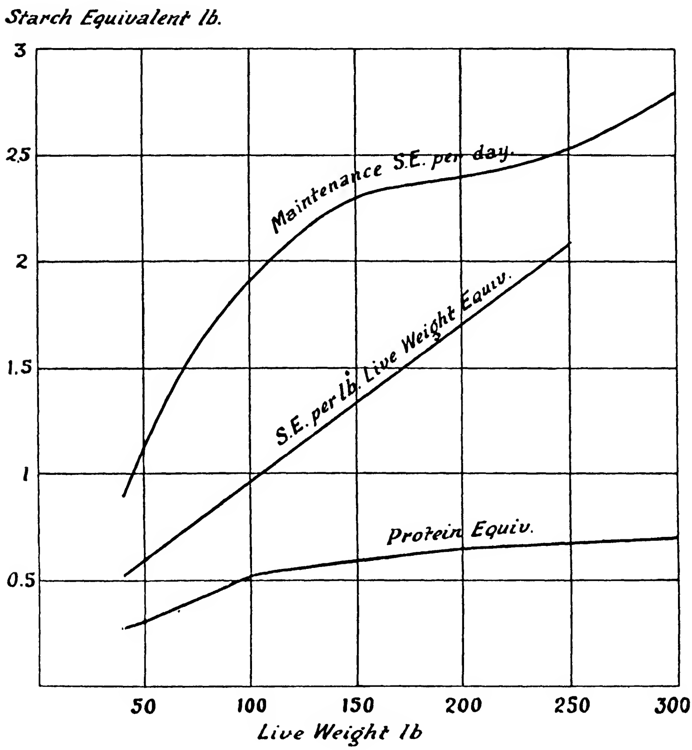

FIG. 5.—FOOD REQUIREMENTS PER DAY OF PIGS.
(After T. B. Wood.)

The rationing of horses is also relatively inexact because of the great difficulty of attaching values to the energy output in what would be called light work or heavy work, ploughing or carting. But the main-

tenance ration may be taken as from about 4 lb. starch equivalent for a 10-cwt. horse, up to 6 lb. for an 18-cwt. horse. The difficulty then comes in measuring the work done in any operation, and there is little exact knowledge as to the factor of conversion of net energy into work. Under the best conditions only about one-third of the net energy (over and above the maintenance ration) is turned into useful work, the rest appears as bodily heat. Everyone knows how hot he gets when performing continuous muscular work; for every foot-pound of work he does he evolves 0·001 Calorie of heat in his own body. A horse ploughing an acre has been estimated to perform about 3 million foot-pounds of work, for which 3,100 Calories of net energy would be required from the food, or nearly 3 lb. of starch equivalent. This is probably an underestimate of the work done in ploughing, for the usual practice is to allow a horse in medium work about 13 lb. of oats a day, in addition to its maintenance ration of hay, and that is about 8 lb. of starch equivalent.

CHAPTER V

THE COMPOSITION OF FEEDING STUFFS

Interpretation of Analysis of a Feeding Stuff. Nature and Composition of Cakes from Oil Seeds. Composition of Cereals and Milling Offals. Peas and Beans. By-products. Composition of Meadow Hay, Seeds Hay, Lucerne and Sainfoin Hay. Value of dried young Grass. Silage

THE function of the three essential constituents of feeding stuffs—proteins, fats and carbohydrates—have already been discussed; we have further to consider their behaviour in the natural mixtures that are the cattle foods grown or bought by farmers. As a rule, the composition of any given cattle food is expressed as follows: Decorticated cotton-seed cake contains—

	Per cent.
Moisture	8·2
Fat	11·9
Proteins	46·2
Carbohydrates (by difference)	21·2
Fibre	5·5
Ash (containing sand = 1·5 per cent.)	7·0
	100·0

The fat really represents the material which is soluble in ether; when dealing with oil cakes and

similar foods derived from seeds, it will consist almost wholly of pure fat, but in the case of green fodders various other materials, e.g. chlorophyll, are dissolved by the ether in the process of analysis and counted as fat. Crude fat would be a more correct title. The proteins (albuminoids of the older books), again, should be called crude proteins or some equivalent term, because the figure expressing them is only obtained by multiplying by 6·25 the total nitrogen contained in the food, thus including as proteins various non-protein nitrogenous compounds such as the amino-acids, amides, and other bodies intermediate between nitrates and proteins. All green fodders contain a considerable proportion of their nitrogen in this non-protein form. The true proteins are nowadays determined separately. Crude fibre is again a purely conventional term for whatever remains undissolved when the food has been digested for some time, first with dilute acid and then with alkali : it represents very approximately a part of the food which can only be imperfectly digested by the animal, and is therefore of much smaller value as food. The ash is a figure of value to the analyst, while the "sand" (that portion of the ash which will not dissolve in weak acids) provides an index of how far the food is contaminated with dirt, mud, sand, etc. Finally, all the rest of the food is reckoned as soluble carbohydrates ; obviously the figure expressing their percentage contains the accumulated errors of the analysis, and is of value only for comparison with other foods. Indeed in Great Britain the seller of feeding stuffs is under no obligations to state the amount of carbohydrates in the food he is selling, though he must state the percentage of moisture, nitrogen and fat. In all foods we find these con-

stituents—fats, proteins, carbohydrates, fibre—and though great differences exist between the various materials thus classed together, according to the food in which they occur, our knowledge is still too imperfect to make it worth while discriminating between them in an ordinary analysis. Of course, besides these main constituents which run the machinery of the body—the fat, carbohydrates, proteins—foods contain a variety of other bodies, the vitamins and minerals to which reference has been made, and those substances which give flavour and affect the disposition of the animal towards its food, although, as far as is known, they do not actually alter its digestibility. The question of flavour is as yet beyond scientific treatment; its influence must be left to the observation and judgment of the skilled feeder of cattle.

The Table which is now available (p. 46) gives not only the composition of the whole feeding stuff, but also of the portion that is digestible.

More recent figures for working purposes are to be found in Bulletin No. 48, Rations for Live Stock, of the Ministry of Agriculture.

The most concentrated of all foods are the meals and cakes, the latter being the residues left after crushing various oil-bearing seeds in order to extract as much oil as will come out by pressure alone. The composition of such cakes will vary with the nature of the seed and its origin, but the amount of oil in the cake can also be greatly modified by the extent of pressure put on and the temperature at which the crushing is conducted. With linseed cake in particular it is customary not to extract the oil as fully as would be possible, whereby the cake is enriched and at the same time rendered softer and easier of digestion. In some cases

TABLE II.—COMPOSITION OF FEEDING STUFFS

	Food Ingredients.									
	Total Percentage in Food.					Digestible Percentage in Food.				
	Total Dry Measure.	Crude Protein.	Oil.	Soluble Carbo-hydrate.	Crude Fibre.	True Protein.	Oil.	Carbo-hydrate and Fibre.	Albuminoid Ratio in Digestible Matter.	Starch Equivalents.
	%	%	%	%	%	%	%	%		lb.
Cotton-seed Cake (Decorticated)	92	41	9	26	8	34	8½	20	1 : 1¼	71
,, (Undec. Egyptian)	88	22	5½	34	20	15½	5¼	20	1 : 2	40
Linseed	91	23	36	23	6	17	34	21	1 : 5½	119
Linseed Cake	88	30	10	34	9	25	9½	32	1 : 2¼	76
Bran	87	14	4	56	9	10	3	45	1 : 5¼	47
Gluten Meal	90	38	4	45	2	33	3½	42	1 : 1½	77
,, Feed	90	26	3	53	6	21	2½	52	1 : 2¾	74
Rice Meal	90	12	12	50	8	6	10	42	1 : 11	70
Grains (dried)	90	20	7	42	16	14	6	33	1 : 3½	50
Maize	89	10½	5	70	2	7	4½	68	1 : 11¼	84
Oats	87	12	6	55	10	9	5¼	45	1 : 6½	63
Barley	86	10	2	67	5	9	1¾	64	1 : 9¾	74
Wheat	87	12	2	69	2	9	1¼	65	1 : 7½	73
Beans	86	25	1½	48	7	19	1¼	48	1 : 2¾	67
Peas	86	23	1½	54	6	17	1	53	1 : 3¼	70
Wheat Straw	86	3	1¼	37	40	¼	½	34	1 : 71	12
Meadow Hay	86	10	2½	42	26	4	1	41	1 : 11	31
Clover Hay	84	13	2½	37	25	5½	1½	38	1 : 7½	31
Swedes	11½	1¼	¼	8	1½	¼	1/10	8	1 : 33	7
Mangolds	12	1¼	¼	9	1	1/16	1/10	9	1 : 92	7

the oil is extracted by chemical means, but the seed residue is then generally used for manure ; as a rule, rape seed is treated in this fashion because it is rarely pure enough to be used afterwards as cattle food, being often mixed with a considerable proportion of mustard seed. In this country the cakes most generally used are those derived from linseed and cotton seed, and of recent years from ground-nut or earth-nut, from palm-kernel, coconut and soya bean.

Many other kinds of seeds are crushed, though the residues are usually worked into some of the compound proprietary mixtures which are so widely sold as oil-cakes.

These oilcakes constitute the richest and most concentrated of all cattle foods, in most cases also their digestibility is very high. At the head stands decorticated cotton cake, since cotton-seed meal still containing its oil unextracted is rarely seen in this country though it is commonly employed for fattening cattle in the United States. The decorticated cake is made from cotton seed from which the husks have previously been removed, the undecorticated cake being made from the whole seed after the cotton fibre has been ginned off. Decorticated cotton cake is extremely rich in proteins and oil, and contains but little fibre ; while it is an excellent food for fattening bullocks and for dairy cows, it must not be given to the latter anywhere near the time of calving, nor should it be fed to calves. There is evidence that it contains some substance which is at times disturbing or even poisonous to cattle, so that cotton cake must always be used with discretion. Undecorticated cotton cake is the favourite adjunct to the food of cattle

fattening upon grass, especially in the early spring; it has certain astringent properties which correct the action of the young grass. When fed to milch cows cotton cake tends to harden and raise the melting-point of the butter made from their milk. In buying undecorticated cotton cake, care should be taken to see that it has not got heated or become mouldy—the smell and taste give fair evidence in this direction; of course, an analysis is of great importance, to see that it contains no undue proportion of husk. The same precautions must be taken over undecorticated cake, of which many inferior samples are made containing an excess of husk, sometimes ground to a powder to disguise it; an excess of cotton fibre also occurs, and is undesirable.

Linseed cake is the most highly esteemed of all the feeding stuffs; it is always relished by stock and never disturbs their health in any way, though if fed in large quantities to milch cows it is apt to render the butter too soft and oily. Linseed cake is particularly valued by graziers at the end of the fattening process, because nothing else will confer the sleek, shining appearance and kindly feel of the skin which comes to an animal "finished" on linseed cake. Linseed cake should be analysed and examined for purity; it should show no reaction when tested for starch, which would only be present as an impurity due to the seeds of weeds, for linseed itself contains no starch. Very hard cakes also are undesirable, because they are low in oil. There is evidence, however, that the very high content in oil which is often attained—12 per cent. or over—is rather an expensive luxury, for just as good results can be obtained with poorer cakes supplemented by a corresponding amount of carbohydrate.

Soya-bean cake is an extremely valuable food for all classes of stock.

It is characterized by a very high percentage of protein, up to and over 40, with 7 per cent. or so of fat of high quality but little carbohydrate. The protein possesses a high nutritive value ; it belongs to the casein group, and in Japan the protein of the soya bean is used for making a kind of cheese, just as at one time it was made the basis of a kind of artificial milk. The fat is a valuable one but has laxative properties. These factors render it inadvisable to feed soya-bean cake in too large quantities. Ground-nut or earth-nut cake is the residue left after expressing oil from what are generally called pea or monkey nuts, the fruit of a leguminous plant, *Arachis hypogea*, grown chiefly in the West African colonies. Both decorticated and undecorticated cakes are made ; both are exceptionally rich in protein and so must be used with discretion. The oil has neither the laxative character of oil from soya beans nor the astringent properties which make undecorticated cotton-seed cake so useful.

Palm-kernel cake is derived from the seeds of the West African palm from which palm oil is extracted ; it is not so rich in protein as many of the cakes but is usually pure and of good quality. Stock take a little time to get used to palm-kernel cake, but it is a very useful ingredient in rations in fattening pigs.

Palm-kernel meal is also on the market from which the oil has been extracted not by pressure but by solvent, so that its proportion in the cake is reduced to 1–2 per cent. Such extracted meals are not so generally esteemed though there appears to be little practical evidence that their value has been deteriorated by the process to which they have been subjected.

Coconut cake is not dissimilar to palm-kernel cake, as a rule a little richer in oil and poorer in protein, but its use leads to a rather soft and oily fat.

Of the cereals, oats are the richest, containing the highest proportion of both proteins and fat; they are valuable for all classes of stock, and always wholesome. Wheat requires more careful feeding and is only regularly used for poultry, for which purpose the bold white wheats are most in demand. It not infrequently happens, however, that milling offals are dearer than the wheat from which they are derived, in which case it may be advisable to buy and grind whole wheat for feeding pigs, even when the farmer wants to sell his own wheat in order to secure the bounty.

In the manufacture of flour rather less than 70 per cent. of the clean wheat grains leave the mill as white flour; the residue consisting of the germ, husks and the layer immediately below them, together with more or less flour proper, constitute the millers' offals which are sold for cattle food. They used to be classified as middlings (the fine samples of which were practically flour discoloured by a small proportion of husk), pollards and bran, but under modern practice in Great Britain only two grades are produced, "weatings" and bran. "Weatings" is the equivalent of what used to be straight-run middlings with a fibre content of less than 5·75 per cent.; "superfine weatings" is the old fine middlings with a fibre content of less than 4·5 per cent.

Middlings and pollards still appear in the price lists, imported from the Argentine. Weatings and middlings constitute one of the largest elements in the ration for fattening pigs and are also included in many

rations for milch cows. Bran is too fibrous for pig-feeding but has considerable value as an ingredient of many concentrated rations because of its laxative properties due to the stimulating action of the fibre on the intestinal movements.

Barley is somewhat poorer in protein than wheat and has rather more fibre, but as a food it appears to agree with all classes of stock. Barley meal is one of the main constituents of the ration for feeding pigs, producing firm and well-flavoured meat and fat. It also enters into the rations for milch cows ; its deficiency in protein can best be remedied by a mixture with bean or pea meal or a cotton cake.

Brewers' grains are also a barley product, being the residue which is left after the malt has been extracted in the " mashing " process. The starch of the grain is then nearly all dissolved by the diastase developed in the germination. They are sometimes sold in their wet state to dairies near a brewery for immediate consumption, but after drying are nowadays a regular article of commerce. They contain a fair amount of protein but are very full of fibre.

Malt culms can occasionally be obtained and consist of the dried sprouts knocked off the germinated barley before it is ground into malt. It is a very digestible and fairly rich food.

Maize is even richer in carbohydrate than wheat or barley, but though valuable in this respect its protein is of very inferior quality, and the grain itself is so hard that portions escape digestion unless it is finely ground. It contains a fair percentage of oil, but when fed in too large proportions to pigs or milch cows, it gives rise to a very soft and oily fat. Maize enters into many commercial preparations and in their manu-

facture a variety of by-products result, which are on the market as cattle foods. Maize gluten feed is a highly concentrated food, rich in protein though again of a poor grade, and very low in fibre and ash ; a small proportion may be used to raise the protein content of the rations of milch cows. Maize germ meal is another valuable food for milch cows and fattening bullocks, very digestible and rich in oil.

Rice meal appears more rarely in the market ; rice itself is almost wholly starch, but the rice meal which is obtained during the preparation of rice for human food is richer in both protein and oil and in mixture may be a useful food.

Beans and peas are both rich in protein ; they are among the most valuable of food for either young growing stock, horses, pigs, or sheep ; an admixture of bean meal is also good in a ration for milch cows. Some of the foreign beans are occasionally dangerous because of the presence of seeds which generate prussic acid during digestion.

Of the different roots, potatoes contain by far the most dry matter (25 per cent.), then mangolds with about 12 per cent., swedes with a little less, and turnips with less than 10 per cent. They are all in the main carbohydrate foods. The potato contains starch, the mangold sugar, while swedes and turnips contain various pectic bodies as well as sugars. A large proportion of their nitrogen is present in the non-protein form, as it is also in cabbage and all green fodders.

In addition to these regular feeding stuffs there are a few supplementary materials in general use. Molasses or treacle is the uncrystallizable residue in the manufacture of sugar, valuable both as a carbo-

hydrate (about 65 per cent.) and also for its sweetness and flavour which makes it a welcome adjunct to various rations. For convenience of handling the molasses is often absorbed by some neutral material such as the pith of the sugar-cane itself or a fibrous quality of peat. These materials add nothing to the feeding value of the contained molasses, and the question is only whether the convenience of handling is worth the extra price.

Then come a number of by-products of the canning and other food preparation processes—fish meal, meat meal, dried blood, cod-liver oil, whale meal, yeast, etc., which may contain very valuable protein and fats, and also essential minerals like phosphate of lime. Their distinctive value, however, is usually the vitamins they contribute to the ration and in consequence they will be considered later.

Again, the composition of what is the most important of all feeding stuffs—grass in all its stages of hay and artificially dried grass, and silage, requires separate treatment.

Occasionally substances are used as condiments or for flavouring, the most common being fenugreek, the seed of a leguminous plant. They are of some service in leading animals to consume a strange ration, or materials like palm-kernel cake which are somewhat distasteful, but they do not add to the digestibility of the ration. Cooking again does not render food more digestible, though by its mechanical action of softening the material it may secure the digestion of hard grains like maize, which have not been finely ground.

The oldest and most universal of all feeding stuffs is hay, the composition and feeding value of which is

extremely variable according to the season and the accidents of the hay-making process. It should be recognized that meadow grass during its growth changes considerably in composition. In its early stages, especially in the flush of growth in the early summer, it is rich in crude protein, up to 20 per cent., though a considerable proportion of the nitrogen is still in the amino-acid stage, and is very digestible, with less than 20 per cent. of fibre. But as it shoots and the flowering heads begin to form the fibre increases and the percentage of protein begins to fall, though as the seed forms the nitrogen mostly passes into true protein. As maturity is passed the amount of fibre grows still further ; some of the seed may be shed, and the grass though still living may lose valuable constituents by washing in the rain. Thus in a season of drought when growth is poor it is bad policy to defer cutting in the hopes of a heavier yield. Even if this is obtained, the farmer loses through the inferior quality and poor digestibility of the hay. The wiser plan is to cut earlier than usual and trust the rain when it does come to produce a vigorous second growth. The hay-making process itself results in some loss to the feeding value of the grass ; even under the most favourable conditions there is fermentation which burns up some of the carbohydrates, and rain will wash out some of the nitrogen and the mineral constituents.

Seeds hay, because of the predominance of clover, is a valuable feeding stuff, though its stemmy nature causes a good deal of waste and brings its starch equivalent below that of good meadow hay. Hay made from lucerne is specially rich in protein and is highly esteemed, e.g. for feeding racehorses. It is, however, difficult to make, for the lucerne easily loses

its leaflets. Sainfoin hay, though not so often seen now, is a very healthy fodder, highly esteemed for sheep. Compared with lucerne it is equally rich in protein and possesses a higher starch equivalent.

The following compositions are taken from the Ministry's Bulletin No. 48 :

	Dry Matter.	Ash.	Protein Equivalent.	Starch Equivalent.
Meadow hay, good	85·7	6·2	4·6	37
,, ,, poor	85·7	5·0	3·0	22
Seeds hay (clover and rye grass)	86·0	6·3	4·9	29
Red Clover hay, good	83·5	6·0	7·0	38
Lucerne hay, in full flower	83·5	8·0	8·0	29
Sainfoin hay, in flower	83·5	7·3	8·6	37

Since the War a method of managing grassland for intensive production has been developed, the essence of which consists in renewing the rich growth of the "flush" period of May and early June by the repeated application of nitrogenous fertilizers. This highly nutritious growth, rich in protein and very digestible, only exists when the grass is short, not more than 6 inches in height. After that time the fibre increases and the protein diminishes until the state of hay grass is reached. The method begins with a good application in winter of phosphates and potash, with lime if the soil needs it, then 1 cwt. of sulphate of ammonia is applied as soon as the weather breaks in early February to one of a series of paddocks, say six in number. The other paddocks receive the sulphate of ammonia at successive intervals of a week. As soon as there is a good bite on the first paddock it is stocked and grazed down closely in a few days, after which

the stock move on to the second paddock, and so on in rotation. After the first paddock has been cleared and harrowed to spread the dung, the application of 1 cwt. of ammonia is renewed, a process which is in turn applied to each paddock after grazing. To apply the method exactly the weather must be propitious and consequently there must always be a reserve of grazing against a droughty period. With this reserve there will be on occasion an excess of grass, and as the method depends upon close grazing, which never allows the grass to run up more than 6 inches, some of the paddocks may have to be cut. This young grass can be dried, and then forms a very valuable fodder with 21 per cent. of crude protein and only 19 per cent. of fibre.

So valuable is this product that it may supply all the concentrated food required on the farm and in many places drying machines are being installed for this purpose. To supply the raw material the required area of grassland is divided into three portions manured at weekly or ten-day intervals, on the basis of cutting after a growth of three weeks or a month. It is necessary to have a special machine to gather up the short grass ; various types of drier are on the market, but all are in rather a tentative stage of development.

A good sample of dried young grass may be expected to possess a starch equivalent of 60 and a protein equivalent of 12, which would give it an energy value equal to that of oats and a protein equivalent little less than that of undecorticated cotton cake. Its value as compared with other concentrated foodstuffs is over £7 per ton. Even that does not take into account the fact that the drying process does not impair the content of carotene and of Vitamin A, so that milk and butter

made on a dried grass ration possess the colour and vitamin content of the summer grazing product. The dried grass can best be used in feeding milch cows or in the winter fattening of cattle or as a supplement in fattening lambs. It is very valuable as a constituent of the poultry ration and a smaller proportion is good in the pigs' dietary.

One of the oldest and most widespread methods of preserving green fodder for winter use, whether grass or crops, consists in turning it into silage by storing it in bulk out of contact with the air. Winter feeding of stock in North America is almost wholly done on maize silage, since the climate will not permit our winter crops—turnips, kales and cabbages—to stand out of doors. The normal adjunct to a farm in the Middle West or in Canada is a tall cylindrical silo made of wood. Such stave silos have been introduced into Great Britain, but among the many types of building that have been tried a cylindrical tower of reinforced concrete, 30 feet high and 12 feet diameter, appears to give the best results. Pits or trenches in the ground are sometimes used or simple stacks which can be loaded with boards and weights ; the conditions that have to be considered are ease of loading and removal, and the proportion of waste along the exposed sides. When a green crop is thus packed into a closed chamber a brisk fermentation sets in, and how rapidly and how far it will proceed depends upon the nature and ripeness of the crop and the amount of air that has been included with the mass. The crops most generally grown for silage in this country are either maize, cut green when the cobs are first forming, or a mixture of oats, vetches and beans, cut when the vetches are still flowering, before the lower

leaves begin to rot. The latter mixture is the best, as the maize does not become mature enough to give the good results obtained from it in America. In either case the crop is carted to the silo, put through a cutter which reduces the maize to lengths of 6 inches or so, and then blown up to the top of the silo. If surplus grass or clover is to be siloed it is improved by mixing in, as the filling proceeds, dry material —chopped straw, pea and bean haulm, even cavings.

While there was a considerable movement to erect silos shortly after the war their use has not extended. The purpose was to replace the root crop by something more easily grown, that came to harvest in good weather and yet provided succulent food for milch cows in winter. Silage is likely to be of most service to men keeping cows on either the light dry soils of England where the turnip crop is precarious, or again on heavy land in the north where both cultivation and harvesting of roots is expensive, and under these conditions silage is still made. But it does involve labour in the cultivation of the crop, and in cutting and carting a considerable weight of material, and again labour in filling the silo. Careful studies of the fermentation process have shown that it causes considerable losses of carbohydrates and by reduction of protein to amino-acids, while the digestibility of the fibre is not increased. Nor is it now regarded as so essential to supply milch cows with large quantities of succulent green food in winter; also the carotene content of the crop is greatly reduced during the fermentation it undergoes in its conversion into silage. When the capital outlay is also considered, silage from arable land crops becomes a relatively expensive crop, which only special conditions will justify.

Of recent years a modified process of making silage has been introduced from Sweden by Dr. A. I. Virtanen, in which the grass or clover is cut and built into a stack, the material being sprayed over with very weak acid (sulphuric or hydrochloric) as the stack is being built. This results in a low-temperature fermentation, with less destruction of the digestible carbohydrates and proteins, nor is the carotene destroyed. This A.I.V. silage process promises to fit in well with some types of farming, e.g. cowkeeping in the open, but it has not been fully tested in this country.

Of course the silage processes can be applied to all kinds of plant residues that are still full of water, e.g. to sugar-beet pulp and again to the pea-pods and haulm that otherwise become a nuisance to the factories where peas are canned. Silage is naturally of very variable composition ; a few examples will show the type of material that results.

	Dry Matter.	Ash.	Protein Equivalent.	Starch Equivalent.
Maize, English . . .	21·0	1·3	1·0	12·1
Pea Haulms and Pods	26·5	2·6	—	—
Sugar Beet, mixed tops and pulp . . .	15·9	2·0	1·1	10·3
Vetches and Oats .	27·3	2·2	1·6	12·8
Rye Grass and Clover (stack)	32·2	2·9	0·5	10·5

Further details will be found in the *Report of a Committee on the Preservation of Grass* (Agricultural Research Council, publ. Stationery Office, 1*s*.).

Oats provide the only straw of much account in feeding ; wheat straw has a lower feeding value and barley straw is disliked because of its dustiness and

the presence of the sharp awns. But all straws vary greatly in response to the season and climate ; the less mature oat straw obtaining in Scotland possesses a much higher feeding value than that usually grown in England. Bulletin No. 48 gives the following comparisons :

	Dry Matter.	Ash.	Protein Equivalent.	Starch Equivalent.
Oat : Spring . . .	86	4·9	0·9	20
Barley : Spring . .	86	4·6	0·7	23
Wheat : Winter . .	86	5·3	0·1	13

The ash is of little value, so much of it being silica.

CHAPTER VI

FOOD ACCESSORIES

Imperfection of Classic Theory of Nutrition. Vitamins and Minerals. Vitamins of importance in Animal Nutrition. Vitamin Supply for Milch Cows, Pigs, Hand-reared Calves, Poultry and Dogs. Mineral Supplements to Rations. Live-stock Diseases due to Mineral Deficiencies

EARLY in the present century it began to become evident that the classical theory of nutrition—the dependence of the body upon supplies of energy and of proteins, did not tell the whole story. The new point of view came with experiments made by Sir Frederick Gowland Hopkins. Rats fed upon a diet of pure carbohydrate, fat, protein and ash in adequate quantities, ceased to grow and eventually began to suffer from a nervous affection causing loss of control of the limbs. The addition of very small amounts of fresh milk to the dietary, amounts insignificant from the energy or protein point of view, removed the trouble and rendered the diet effective. Other substances like yeast and certain green plants also enabled normal growth to proceed.

Further investigation showed that there were several of these "food accessories," or "vitamins" as later they were called, each exercising its own specific action on the bodily functions. The composition of some of these bodies has since been determined, one indeed

can be synthesized from simple materials, and though they are not related they share certain properties in common. They originate in plants and though an organ of an animal may be the richest source of some of them ; usually they have only been gathered up from some vegetable starting-point. They are present in very minute quantities, inappreciable by ordinary analysis, and their mode of action is not as yet understood. Most of them are easily destroyed and cannot long stand up to the temperature of boiling water. Since the recognition of the existence of vitamins they have been proved to play at times a considerable part in the practical feeding of farm animals and have provided an explanation of many troubles that were formerly experienced. This has been particularly the case when intensive production on artificial foods, perhaps indoors, was being practised. Pigs fed exclusively upon barley meal and millers' offals, poultry on a purely cereal diet, were often found to be responding indifferently to the amount of food they were consuming and to be liable to skin and eye troubles and to partial paralysis of the hind-quarters. Cereals are, in fact, both deficient in certain vitamins and in calcium in their ash, and when the animal cannot obtain free access to grass and earth, deficiency troubles are apt to arise.

The vitamins of importance in animal nutrition are distinguished as A, D and E ; the B complex is concerned with poultry.

A is chiefly associated with animal fats, in milk and especially in certain fish oils, as cod-liver oil, whale meat, and fish meal. It is the growth-promoting vitamin and the early stages of its deficiency are generally indicated by sore eyes. It is also present

to some extent in grass, carrots and green vegetables. It is indeed a derivative of carotene, the substance conferring colour on carrots, and it is transmitted from young grass to milk and butter.

Vitamin D is also present in the same animal fats as A, though little of it is found in vegetables. It is preventive of rickets, bone troubles and defective teeth. It is associated with sunlight because ultra-violet light causes its production from ergosterol, a common constituent of grains. Rats when fed only on ordinary maize will develop rachitic symptoms but are protected if the maize is first exposed for a time to ultra-violet light.

Vitamin E is protective against sterility and is chiefly to be found in vegetable fats, e.g. in wheat germ and in green vegetables. The other two well-known vitamins —the anti-neuritic B1 and B2, and the anti-scorbutic C, are less concerned with livestock, though poultry often suffer from lack of B2, and the good effects of yeast preparations with other animals suggests that there may be unrecognized effects of B deficiency.

It will be evident that where animals are reared in a natural way, leading an open-air life with plenty of grazing, there is little likelihood of vitamin deficiency. The need for attention to this factor arises almost wholly in the feeding of pigs and hand-fed calves, and of milch cows and poultry under intensive conditions. It has always been recognized that pigs thrive best when their ration includes a small allowance, even a pint a day, of separated milk or whey, though the latter may be used up to a gallon a day as a definite item in the ration. When milk is not available, or only in a small quantity, the most useful practice is to include in the ration 5 to 10 per cent. of fish meal, which may

be dropped for the last month of their fattening for bacon. It should be white fish meal in order to avoid any risk of imparting a fishy taste to the bacon fat. Preparations of whale meat, cod-liver oil or yeast may take the place of fish meal, though steamed bone flour should also be fed to make up the phosphate of lime of the fish meal. A small allowance of green vegetable daily, kale, turnips, or swedes, is valuable and keeps down skin trouble. Of course, the sows before farrowing, and while the young pigs are still suckling, should have free access to a grass run, but even then should receive fish meal or cod-liver oil in their ration.

Hand-reared calves who cannot have their proper allowance of milk should have cod-liver oil, 4 oz. a day, worked into their gruel. The winter ration of milch cows, particularly when they are being so heavily fed that there is no room in the ration for roots or silage, should include cod-liver oil or fish meal. One of the merits of dried grass as distinct from hay is that it retains the carotene which passes on to milk and butter and gives them both the desiderated yellow colour and the growth Vitamin, A.

Deficiencies in the poultry rations in winter and when not on free range are best made up by the inclusion of fish meal in the mash, by dried grass and a regular allowance of kale and other Brassicas.

Dogs who are fed too exclusively upon a farinaceous diet, e.g. some kinds of dog biscuit, are liable to trouble through vitamin and calcium deficiencies, manifested as nervous affections, skin troubles, and even partial paralysis of the hind-quarters. In the puppy stage dogs should always get some milk, indeed throughout life a little milk each day is desirable. Small quantities of cod-liver oil mixed in the food are also valuable in

the growing stage and should be administered if skin trouble shows itself, when also a little yeast, about a quarter of an ounce in the food, is useful. A small quantity of lightly cooked greens, cabbage or kale, mixed in the daily food, also helps to keep the dog in good condition.

Where animals are being intensively fed indoors, e.g. high-yielding milch cows, fattening pigs or poultry, mineral deficiencies may occur, since the ash of cereals contains very little calcium or salt.

For milch cows a mixture of equal parts of finely ground carbonate of lime and sterilized bone flour should be added to the ration at the rate of 2 lb. per cwt. of concentrated food. An equal weight of salt should be added if the cows are not already provided with a salt lick ; out at grass also cattle and sheep should have access to a salt lick. When fattening pigs are receiving fish meal in their ration their demands for phosphoric acid and calcium will be satisfied and access to chalk mixed with a little salt and wood ashes only is necessary. The same recommendation applies to poultry.

In the Ministry of Agriculture's Bulletin No. 48 a mixture for general use is given, to be added to the dry materials of a poultry mash at the rate of 3–4 lb. per cwt., or at the rate of 2 lb. per cwt. to the concentrates for other animals.

Sterilized feeding bone flour	50 lb.
Finely ground chalk	23
Common salt	20
Sulphur	5
Oxide of Iron	2
Potassium Iodide	4 oz.

The use of Potassium Iodide is only occasionally necessary.

In various parts of the world cases have been found from time to time of deficiency diseases in grazing livestock due to the lack of particular minerals in the soil and consequently in the herbage. As a rule, these troubles are found in the old countries only through long-continued grazing of uncultivated pastures, or in the newer countries where grazing has been attempted without consideration of the specific deficiencies of the soil. As Sir John Orr writes :

> The outstanding symptoms of these diseases are associated with impaired powers of locomotion and lesions of the bones. The affected animals frequently suffer from pica or depraved appetite. Accompanying or preceding these gross signs of disease there are always signs of general malnutrition, such as a rough staring coat, and a degree of emaciation. In young animals growth is stunted and in full-grown females the breeding capacity is affected.

Deficiencies of phosphoric acid and calcium have been observed in some European soils, and deficiency in phosphoric acid in particular is the cause of widespread cattle disease in South Africa—" styfsiekte " and " lamsiekte," which have been prevented by feeding bone meal or manuring the pastures with superphosphate. Phosphoric acid deficiency appears to be very general in East and Central Africa. Similar troubles also occur in Australia, coupled in some instances with deficiency of iron. Iron deficiency causes serious disease in certain parts of the North Island of New Zealand where the soil is derived from pumice from which the herbage can obtain little iron. The administration of citrate of iron has proved an effective preventive.

In the United States deficiency diseases due to lack of calcium or phosphoric acid are known and there is

a large area in which deficiency of iodine causes goitre and impairs breeding. In India McCarrison has traced widespread malnutrition due to lack of phosphorus, of iodine, calcium and common salt.

In the Falkland Islands a continuous deterioration in the size of the sheep seems to be due to lack of calcium, and this appears to be the chief source of the widespread diseases of horses grouped under the name of osteoporosis.

In Great Britain mineral deficiencies are not such as to induce actual disease, though they are probably the source of impaired growth and increased mortality on many hill pastures. The best remedy is the application of basic slag, though as a rule this treatment would only be economic on selected areas. Good results followed from the use of licks containing bone flour, salt and oxide of iron, the trial of which can be made at comparatively small cost.

CHAPTER VII

RATIONS FOR LIVE STOCK

Conditions to be considered in feeding Animals. Protein Equivalent. Calculation of Rations. Rations for fattening Bullocks, Milch Cows, Breeding Sows, Pigs, Sheep, and Horses

THE construction of rations for practical feeding involves several considerations to which in the previous sections no attention has been given. The various animals on the farm possess definite preferences for different types of fodder, or even for particular feeding stuffs or combinations of them that the skilled grazier recognizes but which can hardly as yet be explained on scientific grounds.

Again the appetite has to be considered, to which end a certain bulk in the ration has to be supplied, irrespective of its starch equivalent. On the other hand, the stomach and the digestive system possess only a certain capacity, and when cows are being fed to produce an exceptionally high milk yield the rations must be comparatively concentrated and cannot include the bulk of hay and roots that may be useful enough when the cows are giving a lower milk yield. Pigs again possess small stomachs and deal imperfectly with fibrous foods, so that their rations for economic production should not include materials like hay and

coarse fodder. The food accessories, vitamins and minerals have also to be considered in all intensive feeding, especially indoors. Lastly, the question of price enters and the farmer may often be anxious to substitute a cheaper equivalent for some constituent of his usual ration that has risen in price.

In this book only a very brief consideration can be given to this large and detailed subject, and anyone who is engaged at all deeply in the business of live stock production should furnish himself with Bulletin No. 48 of the Ministry of Agriculture, "Rations for Live Stock," where he will find more detailed information for his purpose. It should, of course, be realized that rations, however scientifically devised, will not alone ensure successful production; farm animals only thrive under the "eye" of the watchful feeder who is on the look out for many details of management. Ventilation without draughts, temperature, sunshine, overmuch effort or competition to obtain food, are all points which the skilful feeder keeps in mind.

In the section that follows the practice of the Ministry's Bulletin No. 48 will be adopted of reckoning the protein requirement in terms of protein equivalent, which is the mean of the figures given for true digestible protein and crude digestible protein. As explained on p. 44, the crude protein includes amino-acids and other nitrogen compounds which are not true proteins but which yet possess a certain value to the animal for the building up of proteins in the body. Protein equivalent is thus calculated by adding together the digestible crude and true protein and halving the sum.

The feeding of calves is still very much of an art and little experimental work has been done on which rationing can be based. The reader should consult Bulletin No. 10 of the Ministry of Agriculture.

CATTLE

The old practice was to fatten bullocks on the turnips and good oat straw, and this method is still followed in the East of Scotland, where both turnips and oat straw possess a higher feeding value than the same materials grown in the South. So bulky a diet is, however, not calculated to give the best results and a diet including some cake and corn will ensure more rapid fattening. The sort of foods that are most valued for the purpose include oats, maize-germ meal, ground-nut cake (decorticated) and cotton cake (decorticated). Linseed cake is highly thought of for finishing as it is considered to impart the right " feel " to the animal and " bloom " on the coat.

The initial considerations are set out on p. 38; for a two-year-old weighing 9 cwt. the maintenance ration must supply 6 lb. of starch equivalent and 1½ lb. of protein equivalent. Then for each pound of live weight increase 2½ lb. of starch equivalent will be needed, so that if the feeder is aiming at an increase of 2 lb. per day, the total starch equivalent must be 6 lb. for maintenance and 5 lb. for production. The total dry weight of the ration should not exceed 22 lb. To take an example, suppose the farmer has available for his bullocks swede turnips, oats, decorticated cotton cake and oat straw, but he does not want to get through his swedes too quickly and can only allow the bullocks 56 lb. each per day, he calculates a ration of 56 lb. swedes, 4 lb. of cake and corn and 20 lb. of straw as follows :

	Per cent.			Total lb.		
	Protein Equivalent.	Starch Equivalent.	Dry Matter.	Protein.	Starch.	Dry.
56 lb. of Swedes . .	0·7	7·3	11·5	0·4	4·1	6·4
2 lb. Decorticated Cotton Cake . . .	34·6	42·0	90·0	0·7	0·8	1·8
2 lb. Oats . . .	7·6	59·5	87	0·15	1·2	1·8
20 lb. Straw . . .	0·9	20	86	0·2	4·0	13
				1·45	10·1	23·0

It will be seen that both protein and starch equivalent are a little below the standard required of 11 lb. starch equivalent and 1½ lb. of protein equivalent, but this can be approximately rectified by doubling the quantity of oats, which would bring the protein up to 1·6 lb. and the starch equivalent to 11·3 lb. There is rather more dry matter than is needed, but the bullocks will adjust that for themselves in picking over the straw.

Now suppose he wants to substitute dried sugar-beet pulp for the swedes; its composition is—protein equivalent 5·1, starch equivalent 60·6, dry matter 90 per cent. The starch equivalent of the beet pulp is about 8 times as big as that of the swedes, so we can start the calculation by reckoning 7 lb. of pulp instead of 56 lb. of swedes.

7 lb. sugar-beet pulp gives 0·36 protein equivalent, 4·6 starch equivalent and 5·6 dry, so that compared with the previous ration we are short of about 0·04 lb. of protein, have half a pound of starch equivalent to spare and are short of a pound of dry matter, which does not matter as there was an overplus in the old ration. If we add a quarter of a pound to the cotton

cake to reinforce the protein and take away 1 lb. of oats to diminish the starch equivalent, we shall get the mixture nearly right—thus :

	Protein Equivalent.	Starch Equivalent.	Dry Matter.
7 lb. Sugar-beet Pulp . . .	0·36	4·6	5·6
$2\frac{1}{4}$ lb. Decorticated Cotton Cake	0·78	0·9	2·0
3 lb. Oats	0·22	1·8	2·6
20 lb. Straw	0·20	4·0	13·0
	1·56	11·3	23·2

The ration will require a slight increase as the feeding progresses, both to meet the extra maintenance ration due to the heavier weight of the animal, and also the larger factor for conversion of starch equivalent into live weight increase. About 2 lb. more starch equivalent per day will be required towards the end of the fattening period.

Cattle fattening on good pasture should not require any artificial feeding, though if they are found to be scouring on the very rapid growth in the " flush " season they should receive ½ lb. a day of undecorticated cotton cake mixed with some chopped straw. As the season advances the grass not only diminishes in quantity but changes in quality, becoming poorer in protein and also in starch equivalent through development of fibre. Indeed, towards the end of the season the grazing may no more than supply the maintenance ration. One may notice in the late autumn and winter how bulky the fæces become, so much of the grass has become undigestible fibre. To finish the later bullocks, therefore, it may be necessary to feed with concentrates

of cake and corn up to a maximum of 5 lb. of starch equivalent per day.

For the feeding of milch cows it has already been stated that an 11-cwt. Shorthorn will require about 7 lb. of starch equivalent and $\frac{3}{4}$ lb. of protein equivalent, and that for each gallon of milk a further $2\frac{1}{2}$ lb. of starch equivalent and 0·6 lb. of protein must be added.

As a rule, the concentrates can be adjusted to supply the productive ration required for the milk, and the maintenance ration can be made up of hay and roots or silage. The Ministry's Bulletin gives an example; a mixture is made of 1 palm-kernel cake, 1 decorticated ground-nut cake and 2 maize. For a four-gallon cow 13 lb. of this mixture will be given to provide the milk, with 16 lb. of average hay. The total requirement is 17 lb. of starch equivalent and 3·15 lb. of protein equivalent. The suggested mixture works out as follows:

	Protein Equivalent.	Starch Equivalent.	Dry Matter.
100 lb. Palm Kernel Cake . . .	17	73	89
100 lb. Decorticated Ground-nut Cake	41·3	73	90
200 lb. Maize	15·3	155	174
Total	73·6	301	353
Per 100 lb. of mixture	18·4	75	88
then—			
13 lb. Concentrates as above . .	2·4	9·75	11·5
16 lb. Hay	0·7	5·55	12·9
Total in ration	3·1	15·3	24·4

The cow's ration is thus a trifle on the low side, but substituting 56 lb. of mangolds for 8 lb. of hay, it becomes :

	Protein Equivalent.	Starch Equivalent.	Dry Matter.
13 lb. Concentrates	2·4	9·75	11·5
56 lb. Mangolds	2·2	3·3	6·7
7 lb. Hay	0·3	2·5	6·0
	4·9	15·55	24·2

The excess of protein equivalent will not matter since so small a proportion of the nitrogenous matter of mangolds consists of true protein.

The bulk of dry matter for a milch cow of this weight should not exceed 25 lb., therefore the ration of cows yielding more than 4 gallons of milk per day can find little room for hay or roots.

The concentrated feeding stuffs most suitable for the rations of milch cows are maize (in moderation), beans, decorticated cotton cake (in moderation), decorticated ground-nut cake, palm-kernel cake, maize-germ meal, weatings and bran.

As already stated, dairy cows fed indoors should have their mineral requirements seen to by adding 3 lb. of a mixture of 2 salt, 1 ground chalk, 1 sterilized bone flour, to each 100 lb. of concentrates. Vitamin deficiency is not likely to occur if the cow is receiving silage or roots or a few pounds of kale or cabbage. An ounce or two of cod-liver oil each day will maintain the Vitamin A in the milk, while the inclusion of dried young grass in the ration will supply the carotene which gives colour to the milk and butter.

A further discussion of the rationing of milch cows will be found in Bulletin No. 42 of the Ministry of Agriculture, by Professor J. Mackintosh.

Pigs

Pigs to be profitable should grow rapidly without any check, and as they possess but a relatively small digestive tract they require a carefully adjusted ration to obtain optimum results. The main food of pigs should consist of cereal meals ; barley meal and wheat offals have always been the basis of the pig's ration. Maize meal and maize gluten meal should never form a large part of the dietary as they produce a soft fat ; on the other hand, bean or pea meal are valuable supplements to the cereal meal to increase the protein content and give firm fat.

Alternatively, palm-kernel meal, decorticated ground-nut meal and extracted soya-bean meal are useful sources of extra protein.

It is highly desirable that the breeding sows from the time of service to farrowing should be on a grass run and the farrowing sties should also have access to a small grass paddock in which the young pigs can run before weaning.

During this period the sows will require for maintenance alone about 3 lb. a day of starch equivalent, with $\frac{3}{4}$ lb. of protein equivalent together with an increasing amount of food to provide when suckling for the growth of the young pigs and the milk. This may be the same mixture as is supplied to the feeding pigs, enriched, however, in its protein content. The maximum ration when the sows are in full milk should supply about 10 lb. of starch equivalent with $1\frac{1}{2}$ to 2 lb. of protein.

A meal made up of 4 stone of barley meal, 2 stone of weatings, and 10 lb. each of palm-kernel cake and fish meal will contain about 14 per cent. of protein equivalent and 70 per cent. starch equivalent, and a ration of 14 lb. of this will supply the maximum requirements of the sow for production. About 4 lb. of the same mixture will supply the maintenance ration, so that the sow should start with this quantity of meal, rising to about 11 lb. at farrowing and then to 15 lb. when in full milk.

For the feeding pigs after weaning the meal given to the sows should have its protein reduced ; to 8 stone of the sow's mixture add 2 stone of barley meal and 1 of weatings, and begin with 2 lb. a day of the new mixture, increasing as they grow up to the limit of their appetite. Alternatively, the feeding mixture can be made up by adding to 2 stone of barley meal 1 stone of weatings and half a stone each of palm-kernel meal and fish meal. Then for the sow's mixture to 6 stone of the above add a further 3 lb. each of palm-kernel and fish meal. Some feeders are afraid lest fish meal should produce a fish taint in the fat, but " white fish meal " should never cause this taint. As a measure of precaution the fish meal may be dropped for a fortnight before the pigs are to be sold as porkers, or for the last month when feeding for bacon. Fish meal has the great value of supplying the needed vitamins and minerals, though a mixture of chalk and ashes with a little salt should also be at hand to which the pigs can help themselves. If some other source of protein is wanted instead of fish meal, then separated milk or whey is the best source of accessories ; indeed, it is commonly held that the best pork or bacon can only be got by using milk regularly in the feeding.

A small quantity of greens, kale or cabbage, or a swede is a valuable addition to the dietary. Other sources of accessories are bone meal, whale-meat meal, dried blood, or yeast, indeed an ounce or two of yeast is indicated if the pigs show any skin irritation.

Sheep

Sheep are mainly fed upon some green crop—turnips, kale, or rape, with a pound or so of hay a day. But to push on fattening lambs some concentrates are required, and a mixture of 2 of barley meal and 1 of decorticated cotton-cake meal is recommended, beginning with one quarter of a pound a day and rising to three-quarters. The ewe in milk also requires a supplementary ration ; pea or bean meal is old practice, but a cheaper ration is one pound a day of a mixture of 2 of crushed oats to 1 of decorticated cotton cake.

Horses

The standard food of horses is oats and hay, say 20 lb. of hay and 10–12 lb. of oats, the oats being increased or reduced according to the work the horses are doing. When the horses are at heavy work in hay-time or harvest they should not be expected to pick up much food by grazing at night. It is sometimes cheaper to replace part of the oats by other food, but this should only be given in proportion to its starch equivalent. Thus 7·3 lb. of maize is the equivalent of 10 lb. of oats and it takes $1\frac{1}{4}$ lb. of bran to replace 1 lb. of oats ; both foods have been given a bad name for horses because they are substituted weight for weight. The Ministry's Bulletin recommends in place of 12 lb.

of oats a mixture of 6 lb. of oats, 2·4 lb. of palm-kernel cake, and 4 lb. of bran.

Poultry

The figures given for the digestibility of feeding stuffs by farm animals do not apply to poultry; Bulletin No. 7—"The Scientific Principles of Poultry Feeding," by E. T. Halnan (H.M. Stationery Office, 1*s.*), should be consulted. A 5-lb. bird requires 2-2½ oz. a day of starch equivalent with ⅓ oz. of protein for maintenance, with a further 1¼ oz. of starch equivalent and ⅓ oz. of protein for each egg.

CHAPTER VIII

VALUATION

Manure Value of Feeding Stuffs. Losses of Nitrogen in making Farmyard Manure. Valuation of Feeding Stuffs on basis of Starch Equivalents. Relative Merits of Simple or Compound Cakes and Meals

ALL feeding stuffs have a certain value to the farm as manure. Fattening cattle, for example, do not retain more than 5 to 6 per cent. of the nitrogen in the food they consume; the rest is excreted, the indigestible portions in the fæces, the digested as urea in the urine. The proportion of phosphoric acid and potash retained is also small. Only milch cows take any considerable proportion of the fertilizing elements out of the food in view of the fact that one gallon of milk contains $\frac{3}{4}$ oz. of nitrogen and $\frac{1}{3}$ oz. of phosphoric acid. It has, of course, long been recognized that the farm is enriched by purchased feeding stuffs; cake-fed dung gives some 50 per cent. greater increase of crop than farmyard manure made under store cattle, and the feeding off of a green crop by sheep which also receive some supplementary feeding stuffs is one of the accepted methods of fertilizing the lighter classes of soil.

The whole of the fertilizing elements excreted do not, however, get back to the soil. In the making and

storage of farmyard manure there are considerable and unavoidable losses of nitrogen, apart from the losses that may be suffered through drainage or washing out of the liquid portion. Even when the animals excrete directly on to the land there will be a variable and uncertain amount of loss through the rapid conversion of the urea into carbonate of ammonia and its evaporation. It has been necessary to assess the amount of fertilizing material which on the average may be supposed to reach the land as manure, so as to estimate both the food value alone of the feeding stuff and also the unexhausted fertility which a tenant leaves behind on a farm on break of tenancy, from purchased food that has been consumed in the later years of his occupation. On the basis of various experiments it is calculated that only one-half of the nitrogen contained in the food will be found in the farmyard manure when it reaches the land. Even this is probably too high, and a better valuation is to allow only two-fifths of the nitrogen, and three-quarters of the phosphoric acid and potash.

The incoming tenant could purchase an equivalent amount of these constituents in the standard fertilizers, so the manure value of the food is calculated from the unit values of nitrogen, phosphoric acid and potash, which vary from time to time but the current prices for which will be found in the weekly Market Report of the Ministry of Agriculture, price 2*d.* (see Vol. II, p. 102). In this way are calculated the manure values of the various feeding stuffs that are set out in Table I, and in the fuller tables contained in Bulletin No. 48 already quoted. This manure value is of some importance in selecting foods, varying as it does from 26*s.* per ton for decorticated cotton and ground-nut cake

to 10*s*. for maize-germ meal, and the grazier who deals in large quantities should take it into account in making up his rations from the cheapest sources.

Comparison of the prices of the various feeding stuffs cannot be as exact a process as the valuation of fertilizers, because there are not in practice any foods which contain a single constituent—fat, carbohydrate and protein—alone. A fair basis of comparison is to divide the price less that manure value of the food by its starch equivalent and so ascertain the cost per unit of starch equivalent. This serves very well for foods of the same character but does not give proper value to the foods rich in protein, which is always an expensive item.

For example, the current price of maize is 120*s*. per ton, its manure value is 7*s*., its starch equivalent 77·6. The cost of one unit of starch equivalent is therefore 120 less 7 = 113*s*., divided by 77·6 = 1*s*. 5*d*. Decorticated cotton cake costs 180*s*., less a manure value of 27*s*. = 153*s*., which divided by its starch equivalent, 68, gives 2*s*. 3*d*. as the cost of one unit of starch equivalent. But cotton cake contains 34·6 per cent. of protein equivalent against 7·6 in maize, so that the unit of protein equivalent in maize would cost nearly 15*s*. against 4*s*. 5*d*. in decorticated cotton cake. The cost per unit of the starch equivalent is given in the Market Report of the Ministry.

A method of evaluating the two constituents, starch and protein equivalents, against one another is set out in the Report of the Departmental Committee on Rationing of Dairy Cows (Stationery Office, 6*d*.), but again the comparisons do not hold good for very different types of food. On this basis the Report works out the food value per ton on the farm of the following

home-grown feeding stuffs, valuations which of course would need revision to-day with the altered prices of feeding stuffs.

	Food value per ton. £	s.	d.
Mangolds	1	0	0
Potatoes	2	12	0
Swedes	1	1	0
Turnips	0	15	0
Marrow Stem Kale	1	8	0
Meadow hay	4	15	0
Seeds hay	3	16	0
Barley	10	2	0
Beans	11	0	0
Oats	9	3	0

From time to time the question is often raised of whether a farmer should buy the simple unmixed foods as set out in Table I and make up suitable mixed rations for himself, or whether he should buy compound cakes, nuts, or meals made up for specified purposes, e.g. dairy cows, pig-feeding or bullock-fattening, by one or other of the great firms manufacturing feeding stuffs. The vendor must declare the percentage of protein and fat in his compound and generally also gives a statement of its starch equivalent, though there is never any declaration of the actual materials—e.g. linseed, sesame, rice, making up the mixture. Calculation will in most cases show that equivalent weights of protein, fat and carbohydrate could be purchased more cheaply ; on the other hand, the good firms are well advised and compound their mixtures very skilfully for their special purpose, more skilfully than the farmer who does not study rationing with care. Again, the firms have latterly attended to the mineral and vitamin contents of their mixtures and

can in some cases point to surprisingly good results through utilizing knowledge that had not become general. It can again be said that with their intimate knowledge of the market they can often take advantage of materials cheap at the time and so keep the price of their compound down, while preserving its percentage of proteins or fats. Such changes in composition may, however, be harmful to the farmer who has carefully adjusted his ration to his particular purpose. The power of thus changing the material does afford the unscrupulous manufacturer the chance of working off cheap but inferior substitutes which still satisfy the analysis. Such cases must, however, be rare with reputable manufacturers, who can only maintain their business if their wares make good and cause purchasers to continue to buy from them.

The farmer who buys in quantity and can follow the theory of rationing and get himself advised by the agricultural organizer of his county, can save money by purchasing unmixed foodstuffs, but the man in the small way of business who has no facilities for storing a variety of foods nor of mixing them properly, will often do better to buy the mixed preparations.

CHAPTER IX

HUMAN DIETARIES

Requirements of Human Beings similar to those of Animals. Economic Considerations. Dominance of Cereals in Human Dietaries. Maintenance Ration of Human Beings—Calories and Proteins. Value of Animal Proteins. Standard Dietaries. Cost of Proteins and Calories in various Foods. Vitamin and Mineral Deficiencies. Sources of Vitamins essential to Health. Importance of Vitamins to Children and Nursing Mothers. Milk as the essential element in their Dietary

THE nutrition of human beings is subject to the same general laws as that of other animals. From one point of view experiments have been less numerous because it has never been so important economically to determine production values for the various foods. Moreover, human beings are much less uniform than cattle, sheep or pigs, which have for countless generations been bred and selected for their capacity to put on fat and reach weight at as early an age as possible. The object of human nutrition is to ensure during the growth period an optimum rate of development without any deposition of fat, and in later years as nearly as possible a stable condition without much variation in weight. It is this prolongation of life, in a healthy condition permitting of physical and mental activity, which introduces into human nutrition many factors that do not enter into the case of an animal being

rapidly fattened for slaughter. The main features of nutrition are however the same in men and animals ; the food materials are the same—carbohydrates, fats, and proteins, with accessories like minerals and vitamins. The food has to be digested ; for each individual there is a minimum maintenance ration to supply the energy of the body at rest, to which has to be added the further amount of food required to supply the energy involved in the physical work done by the individual, a very variable amount according to the man's occupation. As far as can be ascertained, mental work does not make any draft on energy, in spite of the fact that its psychological effect is a great sense of fatigue, often accompanied by hunger. The maintenance ration involves also a certain intake of protein. As with animals, the vitamin content of the food is of great importance, especially for growing children ; and indeed the maintenance of health throughout life is very markedly regulated by the correct adjustment of the supply of vitamins and minerals.

The composition of human dietaries is in a broad sense largely determined by economic considerations. Probably the majority of human beings are living round about the line of bare subsistence, and even above that level only a minority can afford to make an optimum choice of food. Thus we find all the world over that the main feature in any dietary is some cereal,—wheat or rye, with oats and barley as supplements, in central and northern Europe and America ; macaroni wheat in the Mediterranean area ; rice in India, China and Japan ; maize originally in America, but now also largely replacing millet in Africa. The poorer the population the more exclusively does its diet consist of the cereals, simply

because they are the cheapest available sources of energy. In some places roots like potatoes, sweet potatoes, cassava, etc., furnish the chief element of food, again because these roots are easily grown sources of carbohydrate under the prevailing conditions of climate. Animal foods—meat, milk, eggs, etc.—must be more costly than cereals or roots, because, as we have seen earlier, they are only produced out of vegetable materials, and the factor of conversion is a wasteful one from the energy point of view, never less than 5 to 1. Of course, under pastoral conditions milk and meat can be produced from grass without the labour of cultivation, but under this system the land produces a relatively small amount of food and can carry but a thin population. Whenever the population has become dense, as in India, China, Japan, it has to be supported by an intensive cultivation and on a dietary that is almost exclusively vegetarian.

Until comparatively recently men and women had no other means than their appetite of judging whether their nutrition was correct, either in its quantity or its character. But while definite continued hunger was evidence of under-nutrition, malnutrition due to lack of certain constituents or want of balance was not indicated by the appetite, nor again was over-nutrition immediately apparent in a loss of appetite. To a certain extent appetite is a response to habit and people can get into the way of eating far more than is necessary, and of feeling acutely hungry, at any rate for some time, if their dietary is curtailed. Without doubt at the present time the English people, whose means allow them an ample choice of food, are eating very much less than they did formerly, and this not merely in response to a better-balanced dietary.

The first step, then, is to establish for human beings as for animals the basal maintenance ration; how many Calories must it supply and how much protein must accompany the energy intake. Only an average value can be given, so greatly does the amount of external work vary with the occupation, but the figure usually adopted for an adult man in light occupation is 3,000 Calories per day, requiring roughly 3,400 Calories in the food as purchased to allow for lack of digestibility and waste, or roughly 10 per cent. It is known that for men in heavy work, e.g. wood-cutting, the necessary consumption may rise to 6,000 Calories per day. In calculating the food requirements of a population it is usual to regard a woman as equivalent to 83 per cent. of a man, having regard to her smaller weight and surface and on the whole lower output of physical work. Young people have a higher rate of loss of energy per unit of surface than adults, at the same time they are using food for growth requirements, consequently their demands for food are high. Young children up to the age of six can be reckoned as equivalent to half a man, and from the age of fourteen be reckoned as adult males or females respectively. Taking 3,000–3,400 Calories per day as the energy requirement for an adult man, this must contain at least 40 grammes (nearly 1½ oz.) of good protein, or in practice to allow for lack of digestibility and the fact that some proteins are of inferior nutritive value, something like 80 grammes or 3 oz. of mixed proteins in the daily ration are needed.

Some quarter of a century ago an American professor, R. H. Chittenden, brought forward very cogent evidence that these accepted standards for the human maintenance ration were exaggerated. He had in-

duced considerable numbers of people, both students and others in academic circles and squads of soldiers, to carry on for months on dietaries which did not supply more than about 2,300 Calories and 40 grammes of protein per diem, little more than one-half of what they had been consuming. The report of the subjects was that they felt in good health and were exceptionally clear-headed and ready for intellectual work. However, in some cases after years of trial, the experimenters have abandoned this minimum diet. They found they were cutting out every unessential bodily activity, such as crossing their legs when sitting in a chair, and they concluded that they were living too dangerously, without a margin of reserve against an emergency.

So the standard of 3,400 Calories of food as purchased, to include 80 grammes of protein, may be taken as a good working guide to *sufficiency* of nutrition, the more so as it is confirmed by sundry evaluations of the total food consumed by populations in Europe and America.

These are, however, ultimate basic figures and energy can be obtained in different ways, from protein as well as from carbohydrates and fats. The usual factors are that the gramme of either protein or carbohydrate will yield 4·1 Calories and 1 gramme of fat 9·3 Calories. It is generally agreed that it is not desirable to obtain too large a proportion of the daily intake of energy from the consumption of protein, for then the elimination of the excess nitrogen as urea throws too great a strain on the liver and kidneys. Eighty grammes of protein a day would supply about one-tenth of the total energy required, and this is an adequate allowance, though there is evidence that some excess of protein is associated with a feeling of

activity and readiness for work. "Full of beans" appears to have been a divination of physiological truth before the days of dietaries.

But, as has been explained earlier, all proteins are not of equal nutritive value, because some of them are lacking in particular molecular groupings which are necessary to the building up afresh of the body proteins. The digestive process begins by reducing the proteins of the food into their constituent amino-acids, which reach the blood stream, there to be selected for re-combination into the body proteins. But those which are not required or are in excess for the requirements of the new combination are just passed on and burnt, the nitrogen being eliminated as urea.

It is among the vegetable proteins that the chief deficiencies are found ; some of them like the zein of maize are notoriously imperfect, others like the casein of soya beans closely approximate to the casein of milk. On the whole, since the proteins of animal food have been reconstructed within an animal, it is not surprising that they should be generally of higher nutritive value than the vegetable proteins.

On the other hand, though carbohydrates and fat have the same function, merely to supply energy, and though in the feeding of animals carbohydrates can replace fat in the ratio of their calorie value, i.e. 2·27 parts of carbohydrate to replace 1 of fat, it is not desirable in human nutrition to rely exclusively upon carbohydrates. Amongst other things the digestion and assimilation of fats is a longer process than that of carbohydrates, and the effect of a meal deficient in fat dies away too soon and is accompanied by a reduction in the working power. The question of bulk is also important, fats being so much more concentrated than

carbohydrates, which in their turn require very large quantities of water for their digestion and solution. The human alimentary tract is not designed to deal with too bulky a diet in which the energy is nearly all supplied by carbohydrates. But an excess of fats in proportion to carbohydrates will produce the condition known as acidosis, with gaseous fermentations in the lower intestine. The proportion the Calories derived from fat bear to the total Calories varies greatly with different races, climatic conditions and physical work called for, but an amount of 70 grammes (2½ oz.) per day as fat is an adequate allowance out of the standard 3,400 Calories.

TABLE III.—ENERGY VALUE OF SELECTED FOODS PER POUND

	Protein. Grammes.	Fat. Grammes.	Calories. per lb.
Bread, white	32·7	0·9	1,037
Wheat Flour	45·5	7·3	1,660
Oatmeal	54·0	39·0	1,886
Rice	26·8	1·8	1,620
Dried Beans, Peas, etc.	88	2·6	1,558
Beef	80	109	1,348
Mutton	119	85	1,750
Pork	68	111	1,310
Corned Beef	119	85	1,278
Bacon	47	246	2,478
White Fish, fresh	58	1·4	251
Herrings, fresh	66	40	643
Milk (pint)	19	20	380 per pint
Cheese	1·7	159	2,011
Eggs (8 at 2 oz.)	50	46	660
Butter and Margarine	0·9	380	3,540
Sugar	—	—	1,560
Potatoes	8·6	0·1	373
Cabbages	3·2	0·2	88
Apples	1·3	0·9	200
Bananas	2·8	1·2	300
Figs, Dates, Raisins (average)	8·5	1·5	1,140

In Table III are set out the energy value in Calories per lb. of some of the more usual foods. The numbers must be taken as approximations because all natural products vary somewhat in composition and again in the amount of waste that is incurred in preparation and cooking. The rationing of human beings will never be so accurate as that of dairy cows. The figures, however, serve as a means of calculating the relative costs of energy in the different foodstuffs, and the provision of energy is the first consideration in keeping life going. Of course, we have also to take into account the protein, since protein is always dearer than carbohydrate. But we can construct another sort of table as follows:

	Cost.	Calories per Penny.	Protein. Grammes per Penny.
Bread	4-lb. loaf 7*d.*	593	15·7
Oatmeal	2*d.* per lb.	943	27
Rice	3*d.* ,, ,,	540	9·0
Dried Beans, etc.	2*d.* ,, ,,	779	44
Beefsteak	1*s.* 6*d.* per lb.	75	4·4
Bacon	1*s.* 3*d.* ,, ,,	165	3·1
Corned Beef	6*d.* ,, ,,	213	20
Herrings	3*d.* ,, ,,	214	22
Milk	3½*d.* per pint	108	5·4
Cheese	8*d.* per lb.	251	14·6
Eggs	1½*d.* each (2 oz.)	55	4·1
Potatoes	14 lb. for 1*s.*	435	10·0
Cabbages	2*d.* per lb.	44	1·6

It will be seen that the cheapest sources of energy are the cereals and dried peas and beans, though potatoes do not fall far behind. The cheapest sources of protein are again the dry beans and peas, bread and oatmeal, but high-grade protein can be obtained

cheaply from herrings, cheese and corned beef. Fresh meat and eggs are relatively dear, dearer than milk, even at its excessive price of 7*d.* per quart. Indeed, milk is undervalued in the table because it needs no cooking, involves no waste, and is completely digestible.

It has always to be remembered that the figures given above and those usually quoted for the energy values of human foodstuffs are only the crude values based upon analysis without the deductions for digestibility and energy spent in digestion which have been experimentally determined for so many of the cattle foods. Food preparation for human beings does remove a good deal of the waste materials that animals are accustomed to consume, so that the average digestibility is greater ; none the less for such materials as whole-meal bread or raw nuts, a large proportion of what is set down as a source of energy and of protein passes through the digestive tract unchanged and so far is waste. It is not, however, desirable that human food should be completely digestible ; a certain amount of " roughage " or undigested fibre is desirable for the peristaltic actions of the intestine to work upon, and that is the chief justification for the consumption of brown bread and coarse vegetables by people leading sedentary lives.

It is of importance to see to what extent the considerations that have just been advanced for the requirements of the individual are borne out in the observed consumption of food by a family.

Table IV sets out the food consumed by a family for a week ; the first column is a record of the observations of 100 working-class families in Detroit in 1929, but the others are designed dietaries. The second column is a summary of two diets recommended by

TABLE IV.—WEEKLY FOOD CONSUMPTION OF AVERAGE FAMILIES OF COMPARABLE SIZE (3·03–3·58 man value). Lb.

	1	2	3	4
Meat	7·4	7·5	8·5	9·0
Fish	0·6	0·5		3·0
Bread	13·4	24·25	9·6	15·5
Flour	4·0	—	8·1	
Oatmeal, etc.	0·9	1·4	1·3	2·0
Rice, etc.	0·3	1·4	0·8	1·0
Peas, Beans, etc.	0·5	0·9	0·5	0·5
Butter, Margarine	1·8	1·0	1·8	2·0
Lard, Suet, etc.	1·1	0·6	1·0	1·0
Milk	21·6	12·8	35·0	18·75
Condensed Milk	1·3	—	1·2	—
Cheese	0·3	1·4	0·4	0·75
Sugar	3·8	3·8	3·8	4·0
Eggs	2·3	0·2	2·0	1·5
Tea, Coffee, Cocoa	0·7	1·0	1·0	1·0
Potatoes	11·3	14·1	15·1	13·0
Vegetables	10·0	7·5	9·0	10·0
Fruit	10·6		9·4	9·0
Miscellaneous	3·3	2·3	—	2·75
Total lb.	95·2	80·65	108·5	94·75
Persons in family	4·5	4	5	3·72
„ equal to men	3·27	3·03	3·58	3·14

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the Nutrition Committee of the British Medical Association, as ensuring health and working capacity at minimum expense, though providing a little more variety than is absolutely necessary. The third and fourth columns refer to recommended dietaries, the third being a standard of Health and Decency Budget compiled by the Labour Statistics Bureau of U.S.A., and the fourth a "desirable food budget" compiled in 1935 by the Engineers' Study Group on Economics.

TABLE V.—DIETETIC ANALYSIS OF WEEKLY FOOD BUDGET. No. 4. Table IV

	Weight. lb.	Protein. Grammes.	Fat. Grammes.	Carbo-hydrates. Grammes.	Calories.
Meat	9	657	1,000	—	12,500
Fish	2·5	164	46	—	1,290
Bread and Flour.	15·5	550	50	4,090	19,600
Oatmeal, etc.. .	2	100	70	630	3,600
Rice, etc. . . .	1	30	—	360	1,620
Peas, Beans, etc.	0·5	45	—	140	750
Butter	2	—	753	—	7,000
Lard, Suet, etc. .	1	—	410	—	3,700
Milk (15 pints) .	18·75	280	306	410	5,670
Cheese.	0·75	85	122	20	1,500
Sugar	4·0	—	—	1,820	7,400
Eggs (12) . .	1·5	75	70	10	990
Tea, Coffee . .	1·0	—	—	—	—
Potatoes	13	110	—	1,170	5,100
Vegetables . .	10	55	—	300	1,450
Fruit	9	20	—	320	1,400
Miscellaneous .	2·75	—	—	750	2,700
Total . .	94·25	2,171	2,827	10,020	76,270
Daily per "man"	4·3	98·7	129	456	3,470

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This last estimate is further translated in Table V into dietetic units and then in Table VI into cash. It will be seen that the cost amounts to 9*s.* 10½*d.* per head per week, as against a calculated average national expenditure of 9*s.* per week. On the other hand, B.M.A. ration (Column 2) would only cost 6*s.* per head per week, because it substitutes bread, oatmeal and the like for some of the meat, fish, milk, eggs, fresh vegetables and fruit of the more desirable dietary set out by the Engineers.

So far the energy value and protein content only of the foodstuffs have been considered, because

TABLE VI.—COST OF WEEKLY FOOD BUDGET, Table V
Average better quality retail prices, Oct., 1935

	Weight. lb.	Price. s.	d.
Meat	9	9	0
Fish	3	1	9
Bread and Flour	15·5	2	10
Oatmeal, etc.	2	1	0
Rice, etc.	1		3
Peas, Beans, etc.	0·5		2
Butter	2·0	2	0
Lard, Suet, etc.	1·0		7
Milk (15 pints)	18·75	4	6
Cheese	0·75		9
Sugar	4		10
Eggs (12)	1·5	1	6
Tea, Coffee	1	2	0
Potatoes	13	1	1
Vegetables	10	2	6
Fruit	9	4	0
Miscellaneous	2·75	2	0
Total	94·75	36	9

the primary purpose of food is thus to keep the machine running and so the broad outlines of every dietary—personal, family or national, are determined. But it is imperative also to take into account the supply of vitamins, minerals and such food accessories, especially so at the present time when the increased urbanization of life and the industrialization of so many of the processes of food preservation have removed or reduced the food accessories in the modern diet. For example, the modern methods of roller milling to make flour completely remove the outer husks and the germ of the wheat grain in order to produce the whitest flour, because that whiteness carries with it a guarantee of the soundness, cleanliness and purity of the flour.

But the husks and germ of wheat contain vitamins B1 and E and their absence in white flour might be of consequence in a diet consisting very largely of bread. In an ordinary mixed diet these deficiencies are covered, but still for growing children and people leading a sedentary life brown bread is generally better than white, despite its slightly lower calorie value and digestibility. The polishing to which rice is subjected in its preparation for market has been found to induce the serious nervous disease known as beri-beri, again due to the removal of those portions of the husk containing Vitamin B1.

Speaking generally, the cereals contain relatively small amounts both of vitamins and of calcium compounds; in certain cases, again, the cereal proteins are of inferior value. Pellagra is a disease of the digestive system and the skin which is found in southern Italy and Spain and other countries where maize forms an excessive proportion of the diet. It is due to deficiency of Vitamin B2, though the incomplete nature of the maize protein, zein, may also be a factor in the disease. The vitamins are generally more abundant in those parts of the animal which are commercially classed as offals; consequently tinned and preserved foods, from which what seems to be redundant and less valuable is removed as far as possible, are likely to have a lower vitamin content than meats prepared and cooked on old-fashioned lines. Cooking is in itself a source of loss to the vitamins, particularly the higher temperatures employed in canning processes.

It has already been explained that plants are the only makers of vitamins, the vitamins to be found in animal preparations being derived from the

plants upon which the animals have fed. It is therefore of importance to include in the human dietary a certain proportion of fresh plant material, and though the vitamin content of different plants varies very greatly the largest amounts are always to be found in the young leaves and freshly germinated shoots. It is on record, for example, that one of the British forces in the Mesopotamian Campaign was so cut off from supplies of fresh food as to begin to suffer from scurvy. One of the officers, recalling some recent science he had read, was allowed to experiment by germinating some of the horse corn that was available, an Indian leguminous grain called gram. When the shoots had grown for an inch or two they were made into a sort of porridge a little of which was quite effective in stopping the attacks of scurvy. At one time scurvy was a dreadful scourge to seamen engaged on long voyages without fresh food until it was discovered that it could be prevented in the first instance by eating certain green plants or by the daily consumption of a small quantity of lemon-juice. From that time lemon-juice became a regular part of the ration for all sailors on long voyages, but the accident that it was called in the Navy "lime-juice" led in later years to a disaster. In 1875 the British Navy sent an expedition to penetrate the Arctic ice, equipped with everything the knowledge and resources of the period could suggest. The "lime-juice" for the expedition was a gift from the chief company growing limes at Montserrat in the West Indies. The expedition was a failure, chiefly because the sledge parties suffered severely from scurvy, despite the regular rations of lime-juice. It was only after half a century that Dr. Harriette Chick arrived at an explanation of

the breakdown, when she discovered that lime-juice proper, such as the expedition carried, contained little or none of the anti-scorbutic Vitamin C, whereas the lemon-juice which the Navy had previously used was a good source of that protective vitamin.

It is, of course, true that men and women have grown up and lived long and healthy lives for countless generations before vitamins and food accessories were thought of, but none the less it is evident that under the changed conditions of modern life large elements of our population do not obtain adequate supplies of them, particularly at critical periods of their life, and that in consequence certain conditions of inferior development and of susceptibility to positive disease are set up. These troubles have arisen to a large extent from the lack of gardens that has followed the growth of the industrial towns, whereby the essential element of fresh vegetables has become relatively neglected. Doubtless people of the middle and upper classes who enjoy a varied dietary, obtain instinctively all the food accessories they need, but large sections of the workers, who in any case are living near the subsistence level and must restrict their expenditure to the cheapest foods, do suffer from malnutrition. Even when the question of cost does not enter malnutrition does arise through ignorance, especially among children, and most critically in the pre-natal and post-natal periods of the pregnant and nursing mother. It is not uncommon also to find adults dropping into habits of eating which do keep them at a low level of general health through a deficiency of one or other food accessory.

The vitamins of importance to ordinary dietaries in this country are labelled A to E, and their action may

be summarized as follows: Vitamin A is essentially the growth vitamin and is therefore of prime importance in the feeding of the expectant mother and of young children. It is present in most animal fats but probably in the largest proportion in the fats of certain fishes, the preparation of halibut-liver oil being one of the most concentrated. Cod-liver oil is a well-known and valuable source, but it is also present in the oily fishes, herrings in particular. It has already been pointed out that herrings, if sold at a price in reasonable relationship to the price the fisherman is paid for them, are among the cheapest sources of high-grade proteins and of energy, so that when their vitamin value is also considered they become one of the most valuable elements in the British dietary, one that does not receive the appreciation it deserves. The neglect of the herring is the more inexcusable in view of the fact that the gourmet ranks the herring among the half-dozen fishes of finest flavour that reach the British market, in the same category as the salmon, the sole, and the red mullet, and above the turbot and the halibut. Sprats share some of the qualities of the herring and are even cheaper and for that reason more looked down upon. Dried herrings—kippers and bloaters—share the excellences of the fresh herring and would be more esteemed were it not for the fact that out-of-condition herrings are often selected for kippering and even then are cured by chemicals instead of honest smoking.

The other all-important source of Vitamin A is milk, and to some extent its derivatives butter and cheese. The visible difference in physique between the upper and lower classes in England, as for example the children in Eton and its preparatory

schools, as compared with the corresponding age groups in the elementary schools of the country, is very largely due to the different amounts of milk they have been receiving. It is reasonably probable that in one generation the working-class population could be graded up from C3 to B2 if all the children up to the age of sixteen were assured their due allowance of milk.

Green vegetables are other sources of Vitamin A, indeed it has latterly been ascertained to be a derivative of carotene which is developed in young grass and thence finds its way into milk and in turn into butter. Winter milk, in the production of which grass plays so small a part, is white through deficiency in carotene, and so is the butter derived from it.

Vitamins B_1 and B_2 protect against polyneuritis, beri-beri and other nervous and digestive diseases, which attend the excessive consumption of cereals that have been over-prepared. The chief source of these vitamins are the outer coatings of cereal grains and yeast. Disease from lack of Vitamin B is not, however, common in Great Britain.

The anti-scorbutic Vitamin C has been already alluded to ; its chemical nature has been ascertained and it can be synthesized. It is of importance in the nutrition of children and it cannot be ignored in the adult dietary, though sufficient deficiency to result in actual symptoms of scurvy is rare and its manifestation is usually in minor skin troubles. The best sources of the anti-scorbutic vitamin are orange-juice (of immense value to children), lemon-juice (already indicated for use at sea), tomatoes, spinach, cabbage and swede turnips and watercress. Fresh milk and green vegetables and fruit also contain Vitamin C. This is one of the vitamins most readily destroyed by heating and

vegetables of the Brassica and Spinach class in which it is abundant should in consequence never be long cooked.

It is reported that during the Great War members of a certain African tribe brought to the south of France for wood-cutting were found to be developing scurvy though supplied with a liberal and balanced dietary of meat and vegetables. Inquiry showed that it was customary in the camp to make a stew of all the food materials issued and to put it into a cauldron which was kept on the boil all the day under the charge of one man while the rest were at work. The scurvy was stopped by reducing the issue of firewood so that the stew could only be boiled for a limited time.

Vitamin D, the anti-rachitic vitamin, is of the greatest importance in stopping the onset of rickets in children and in ensuring proper development of the teeth. It is intimately bound up with illumination, for it has been shown that ultra-violet light transforms ergosterol, a very general constituent of animal and vegetable tissues, into Vitamin D. The sources of Vitamin D are the animal fats in which it is found with Vitamin A, but not, however, in green vegetables.

Vitamin E is largely concerned with fertility ; its chief sources are vegetable fats, liver and eggs, but deficiencies of Vitamin E are rarely pronounced in British dietaries.

Speaking broadly and generally, the recent knowledge of vitamins calls for the modification of the ordinary British dietary chiefly as regards a further provision of milk for women of the child-bearing age and for children. At the same time all the poorer classes of the community should receive an increased, and that means a cheaper, access to green vegetables

of all kinds. All classes of the community need to realize, as far as their means permit, the great value of animal proteins and fats.

Milk, though dear from the food point of view, is essential to expectant mothers and growing children up to at least half a pint a day. Meat is necessarily dear, but the better food values as well as greater vitamin content is to be obtained from the offals than from the choice joints. Eggs again are dear, but considering their perfect digestibility, the extremely high nutritive value of their proteins, and their richness in vitamins, are amongst the most valuable elements of diet, especially for children and women of child-bearing age. The oily fish, and especially herrings, are the best and cheapest sources of good proteins, fats and essential vitamins, for people who are driven by lack of means to depend upon cereals and dried grains for the substantial portion of their food. Potatoes are relatively cheap as fuel though of no special value as sources of vitamins; they should always be cooked in their skins; green vegetables, such as cabbage, sprouts, and spinach, are of great value even in small quantities, out of proportion to their cost.

In the same way a little uncooked vegetable—watercress, mustard and cress, lettuce, onion—is almost essential to any dietary, whether of rich or poor, and fresh fruits, especially oranges, have a value far beyond their function as a fuel.

While it is essential that the feeding of children should be thought out carefully, as soon as adults have satisfied themselves that their meals are sufficiently varied and include some milk and green vegetables, the less they think about dietaries the better. Food faddism is a disease easily contracted.

Each of the constituents of food—carbohydrates, fats or proteins—can be a source of increase of weight, so that the way to prevent obesity is to eat less generally rather than to begin selecting among the kinds of food, though there are grounds for supposing that excess of carbohydrates most predisposes to fatness.

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INDEX

INDEX